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ENGINEERING DESIGN HANDBOOK

PACKAGING AND PACK ENGINEERING

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

MARCH 1972

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, DC 20315

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ENGINEERING DESIGN HANDBOOK
PACKAGING AND PACK ENGINEERING

CHAPTER 1
INTRODUCTION TO MILITARY PACKAGING

CHAPTER 2
FUNDAMENTALS OF PACKAGING DESIGN

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PREFACE

This handbook is one of a series covering engineering principles and fundamental data needed in the development of Army materiel, which (as a group) constitutes the Engineering Design Handbook Series of the Army Materiel Command. The handbook is a revision of the one published in 1964.

Included in this handbook are the fundamental principles, policies, and limitations of military packaging and pack engineering. Also included is information concerning basic causes of deterioration, methods of preservation, types of preservatives and packaging materials available, natural and transportation environment encountered, cost and human engineering factors, distribution system limitations, and other special military packaging considerations. All chapters of the handbook have been revised and updated to include the latest packaging engineering developments. Three new chapters have been added in the areas of exterior protection, marking, and testing and inspection. Design parameters for military packaging differ importantly from those required for commercial efforts. The primary intention of this handbook is to serve as an introduction to military packaging and pack engineering. A major portion of the text is devoted to a broad treatment of the subject, emphasizing the why of military packaging and directing the user to other authoritative publications for information on how to perform specific engineering tasks.

This handbook was revised by Ryco Engineering Incorporated,[1] Warren, Mich., under subcontract to the Engineering Handbook Office of Duke University, prime contractor to the U.S. Army for the Engineering Design Handbook Series. Technical guidance and general assistance were provided by an Ad Hoc Working Group as follows: Clair L. McDermit, Chairman, U.S. Army Tank-Automotive Command; Joseph V. Budelman, U.S. Army Aviation Systems Command; Frank J. DePalma, U.S. Army Electronics Command; Herbert W. Maas, Jr., U.S. Army Mobility Equipment Research and Development Center, Joseph P. Akrep, U.S. Army Natick Laboratories; Howard Weiner, U.S. Army Munitions Command; Arnold W. Voss, Tobyhanna Army Depot; and Samuel A. McFate, U.S. Army Weapons Commnad.

The Engineering Design Handbooks fall into two basic categories, those approved for release and sale, and those classified for security reasons. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. It will be noted that the majority of these Handbooks can be obtained from the National Technical Information Service (NTIS). Procedures for acquiring these Handbooks follow:

[1]William Dolunt, Project Engineer, Paul Sandor and Joseph Nerone, Technical Writers

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CHAPTER 1

INTRODUCTION TO MILITARY PACKAGING

This chapter presents the general purposes and objectives of military packaging and reviews the primary considerations involved in their accomplishment. The significant role of the packaging engineer and the fundamental differences between military and commercial packaging are also described.

1-1 MILITARY PACKAGING POLICY

The nature of the military procurement and supply system makes it imperative that a consistent packaging policy be implemented. Determining factors include a multiplicity of manufacturers and manufacturing conditions, a variety of transportation and storage conditions, global distribution, and insufficient information about the ultimate destination of an item.

1-1.1 PURPOSE

The basic purpose of military packaging is to assure that items will be fit to perform their intended functions when the time comes for them to be used. Packaging must protect an item from the time of production, through transport and storage, until delivery to its ultimate user. Protection during transport, which includes both handling and carriage, must be achieved while complying strictly with Department of Transportation (DOT) and military transportation regulations. Military items may be stored for indefinite periods of time in both protected and unprotected storage. Packaging must protect the item against physical damage and environmentally induced deterioration during this storage period. In addition, packaging must, in many instances, incorporate provisions for inspecting and performing maintenance on the packaged item (Ref. 1).

1-1.2 OBJECTIVES

It is the aim of the military packaging policy to achieve a high degree of packaging protection in a uniform, efficient, and economical manner. In general, this requires that similar items be preserved, packaged, and marked in a similar way; and that the number and type of packaging requirements and packaging materials used be kept to the minimum consistent with the desired protection. The resulting uniformity facilitates efficient procurement, receipt, storage, inventory, shipment, and issue of supplies and equipment.

Inherent in the objectives of military packaging policy is the elimination of excessive packaging, where excessive packaging is the use of extra or more expensive types of preservation, packaging, or packing materials than necessary to adequately protect an item. Excessive packaging can be avoided by strict adherence to good packaging principles, and by giving full consideration to storage, shipping, and end-use factors (Ref. 2).

1-1.3 DEFINITIONS

Packaging engineering embraces not only techniques used in packaging, but those used in packing as well. See Ref. 3 for a complete glossary of packaging terms.

1-1.4 METHODS OF EXPRESSING PACKAGING DATA

Packaging and packing requirements may be prescribed by a variety of documents. The most commonly used include packaging data sheets, Federal and Military Specifications and Standards, purchase descriptions, and drawings (Ref. 4).

Data sheets are generally used to document the packaging requirements of replenishment type items. They may also be used for major items when the packaging details can be conveniently and accurately described on the form.

Specifications explicitly state the packaging and packing requirements that must be met when packaging items or equipment. They define methods to be used or state the properties and characteristics that must be met by materials. Specifications have as their aim the use of efficient and economical materials and methods, and the achievement of economy through standardization. The specifications serve as guides for procure-

ment, as well as guides for packaging personnel and inspectors. When referenced in contracts, they become part of the contract and serve as legal documents.

There are two types of coordinated specifications used in military packaging–Federal and Military. Federal Specifications cover those materials, products, or methods of interest to, and in common use by, two or more Federal departments, at least one of which is civilian. Military Specifications cover materials, products, or methods used exclusively or predominantly by military activities. In addition, there are limited coordination specifications that are prepared by a single service or command for their particular use, but which can also be utilized by other branches of service.

A standard is a document that established engineering and technical limitations and applications for items, materials, methods, designs, and engineering practices (Ref. 5).

Purchase descriptions, which consist of data normally prepared for publication in a Military Specification or Standard, may be issued when the need for the data is extremely urgent or when information is for one-time usage. The content and format should conform to applicable requirements of specifications and standards.

For certain items a drawing will be required to show the packaging requirements. When needed, the drawing is the preferred document for prescribing packaging.

1-2 ROLE OF THE PACKAGING ENGINEER

The packaging engineer is responsible for the development and engineering execution of all technical data pertaining to the preservation, packaging, packing, processing, and marking of all supply items. His functions and responsibilities are closely related to activities of supply management, field service maintenance, procurement, and production. Major areas of his responsibility include:

a. Development and preparation of all packaging, packing, and processing technical requirements for inclusion in data sheets, Military Specifications and Standards, purchase descriptions and drawings, and for use as source data in field-type documents such as Technical Bulletins and Technical Manuals.

b. Determination and recording of shipping weights, sizes, and cubes of packaged, packed, or processed items of supply, for use by other interested activities.

c. Furnishing of packaging engineering support to field service activities and other applicable authority as required or requested.

d. Consideration of the delaying effect packaging engineering requirements have on production by the specification of unobtainable or unusual packaging methods or materials.

e. Assurance that packaging documentation contains proper provisions for applicable marking requirements. Marking includes item identification, contract, shipping, and required package marking (Ref. 6).

Procedures, methods, and materials specified by packaging engineers must be capable of accomplishment and readily available to packaging and processing organizations in both the industrial and military areas of operation. This requirement is necessary because an item may–as a result of split shipments, package damage, or extensive time in storage–be packaged, packed, or processed by military activities as it progresses through the supply system from point of manufacture to the user.

The packaging engineer must be acquainted with a wide variety of scientific and technical fundamentals in varying fields such as supply system, distribution, and storage. This range of knowledge and skills is important not only for the selection of packaging materials and methods, but also to make possible a close and beneficial relationship between packaging engineering and design and development engineering. Because the availability of packaging data at the time of bid is essential to proper cost estimating for bidding, the packaging engineer should be furnished available prototype and pilot models of end items to facilitate preparation of preliminary or final packaging engineering data. Fig. 1-1 illustrates the role of packaging engineering.

1-3 PACKAGING AND PACKING METHODS

1-3.1 CRITERIA TO BE CONSIDERED

From the military standpoint, good packaging and packing methods are those that protect material from deterioration and damage at a minimum cost. In determining the best method, the first four criteria listed are usually the primary considerations. The remaining six criteria may become important considerations under certain conditions (Ref. 7).

(1) Does the method afford the required protection?

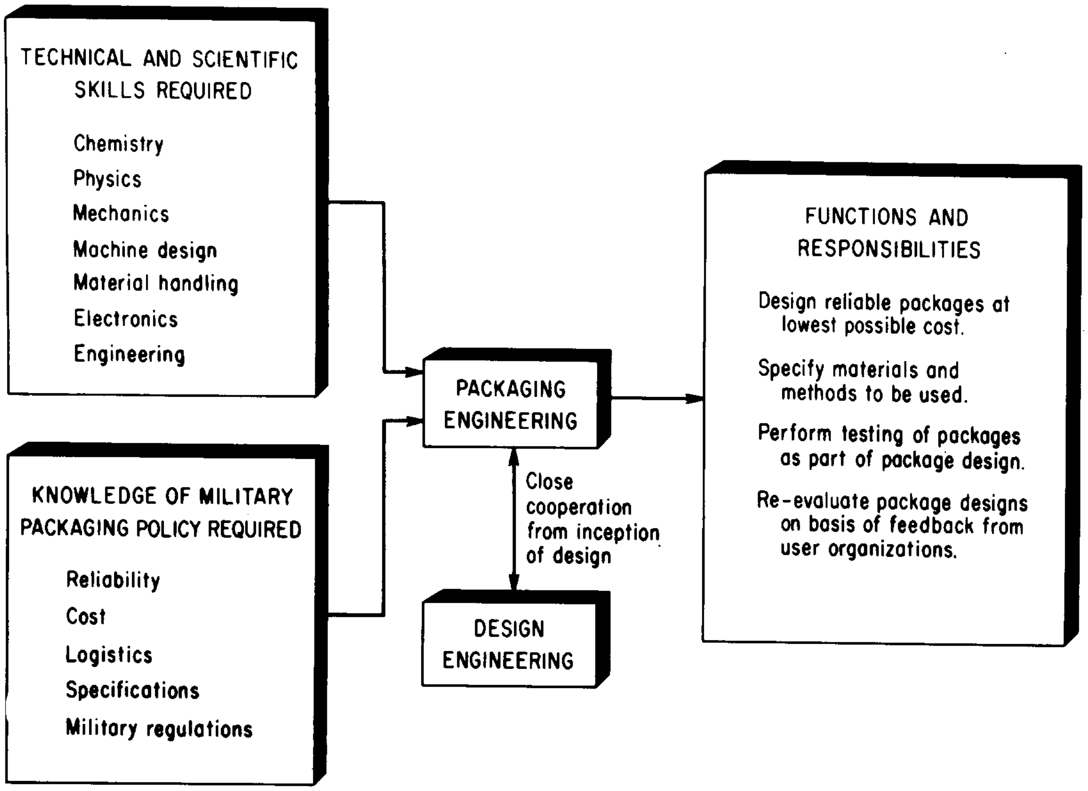

Fig. 1-1. Role of Packaging Engineer

(2) Does the method result in the lowest cost consistent with required protection?

(3) Does the method permit minimum depreservation effort at time of use?

(4) Does the method result in the least cube and weight consistent with required protection?

(5) Can the method be easily adapted for mechanization when conditions, such as quantity to be procured, warrant?

(6) Does the method provide for reuse of containers for recoverable and repairable items?

(7) Is the method consistent with quantity end-use?

(8) Does the method provide continued protection for more than one like item in a unit pack until the contents are depleted?

(9) Does the method promote uniformity in the application of packaging methods?

(10) Does the method meet statutory requirements?

1-3.2 PROTECTION LEVELS

The concept of levels of protection was adopted to permit the military services to state their requirements objectively. Usually, the level of protection to be used is not determined by the packaging activity. Supply management designates the desired level of protection to be used in the packaging and packing of material for shipment and storage, and provides basic detailed packaging requirements for each level. The level of protection as specified in procurement documents is dependent on known use and storage factors. The level of packaging and packing protection required to maintain the item from time of procurement to use should be provided–to the maximum practical extent–at the time of initial procurement.

Military levels of protection are described in terms of the performance expected of the package or pack and must be translated into specific technical or design requirements for individual items or categories of items.

The following levels of protection apply equally to packaging and packing (Refs. 8 and 9):

a. *Level A.* The degree required for protection against the most severe conditions known or anticipated to be encountered during shipment, handling, and storage.

(1) *Design Criteria.* Packaging and packing designated Level A should be designed for direct exposure to all extremes of climatic, terrain, operational, and transportation environments without protection other than that provided by the package and pack. The conditions to be considered include, but are not limited to:

(a) Multiple rough handling during transportation and in-transit storage from manufacturer to ultimate user.

(b) Shock, vibration, and static loading during shipment, including deck shiploading and offshore or over-the-beach discharge, to ultimate user.

(c) Environmental exposure during transit where port and warehouse facilities are limited or nonexistent.

(d) Extended unimproved open storage in all climatic zones, particularly while under static loads imposed by stacking.

(e) Special package and packing features for field and combat operations (handling and utility).

(f) Special features as required by combat development agencies.

b. *Level B.* The degree required for protection under conditions known to be less severe than those requiring Level A, but more severe than those for which Level C is adequate.

(1) *Design Criteria.* Packaging and packing designated Level B should be designed to protect items from physical and environmental damage during shipment, handling, and storage for conditions other than those identified herein for Level A or Level C protection. In general, the following criteria will determine the requirements for Level B design:

(a) Multiple handling during transportation and in-transit storage.

(b) Shock, vibration, and static loading of shipment worldwide by truck, rail, aircraft, or ocean transport.

(c) Favorable warehouse environment for extended periods.

(d) Effects of environmental exposure during shipment and in-transit transfers, excluding deck loading and offshore cargo discharge.

(e) Stacking and supporting superimposed loads during shipment and extended storage.

(f) Special features as required by military and technical characteristics, and logistical considerations.

c. *Level C.* The degree required for protection under known favorable conditions during shipment, handling, and limited tenure of storage.

(1) *Design Criteria.* Packaging and packing designated Level C should be designed to protect items against physical and environmental damage during known favorable conditions of shipment, handling, and storage. In general, the following criteria will determine the requirements of Level C:

(a) Limited handling during transporatation and in-transit storage.

(b) Shock, vibration, and static loading during the transportation cycle.

(c) Controlled warehouses environment for temporary periods.

(d) Effects of environmental exposure during shipment and in-transit delays.

(e) Stacking and supporting superimposed loads during shipment and temporary storage.

As can be seen from the preceding definitions, the level to which a particular item is packaged is determined by the distribution requirements of the item. The degree of protection afforded within a particular level is based on the nature and characteristics of the item.

The design criteria expressed for Level C is intended for use (1) where specific knowledge is available to the designer as to shipping conditions relative to distance and mode of transportation, and (2) where the period

of time from manufacture to the time of use is known to be shorter than that which applies to items entering normal supply channels. Because of this lesser period, and the reduced number of times that an item would be handled from manufacturer or depot to user, some features of the physical and environmental protection may be deleted in the interest of economy. It must be recognized that all items entering a distribution system may be exposed to identical shock and vibration forces; however, they will not be exposed to the frequency of such forces as would apply to materiel being designed for Level A or B.

1-4 MILITARY vs COMMERCIAL PACKAGING

The requirements of military packaging and resulting methods and materials used will differ greatly from those of commercial packaging. The principal areas of difference are shown in Fig. 1-2.

REFERENCES

1. AR 700-15, *Logistics (General) Preservation, Packaging, and Packing.*
2. AR 740-17, *Storage and Shipment of Supplies and Equipment, Excessive Packaging.*
3. FED-STD-75, *Glossary of Packaging Terms.*
4. Defense Standardization Manual 4120.3M, *Standardization Policies, Procedures and Instructions.*
5. AR 715-50, *Procurement Standardization Handbook Specifications and Qualified Products List.*
6. MIL-P-116, *Preservation, Methods of.*
7. AMCR 746-2, *Marking and Packaging of Supplies and Equipment.*
8. AR 705-8, *Department of Defense Engineering for Transportability Program.*
9. TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. II.

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Joint Military Packaging Training Center, *Course Outline,* Aberdeen Proving Ground, Maryland, 1962.

M-200 (AR 715-10), *Standardization Policies, Procedures and Instructions.*

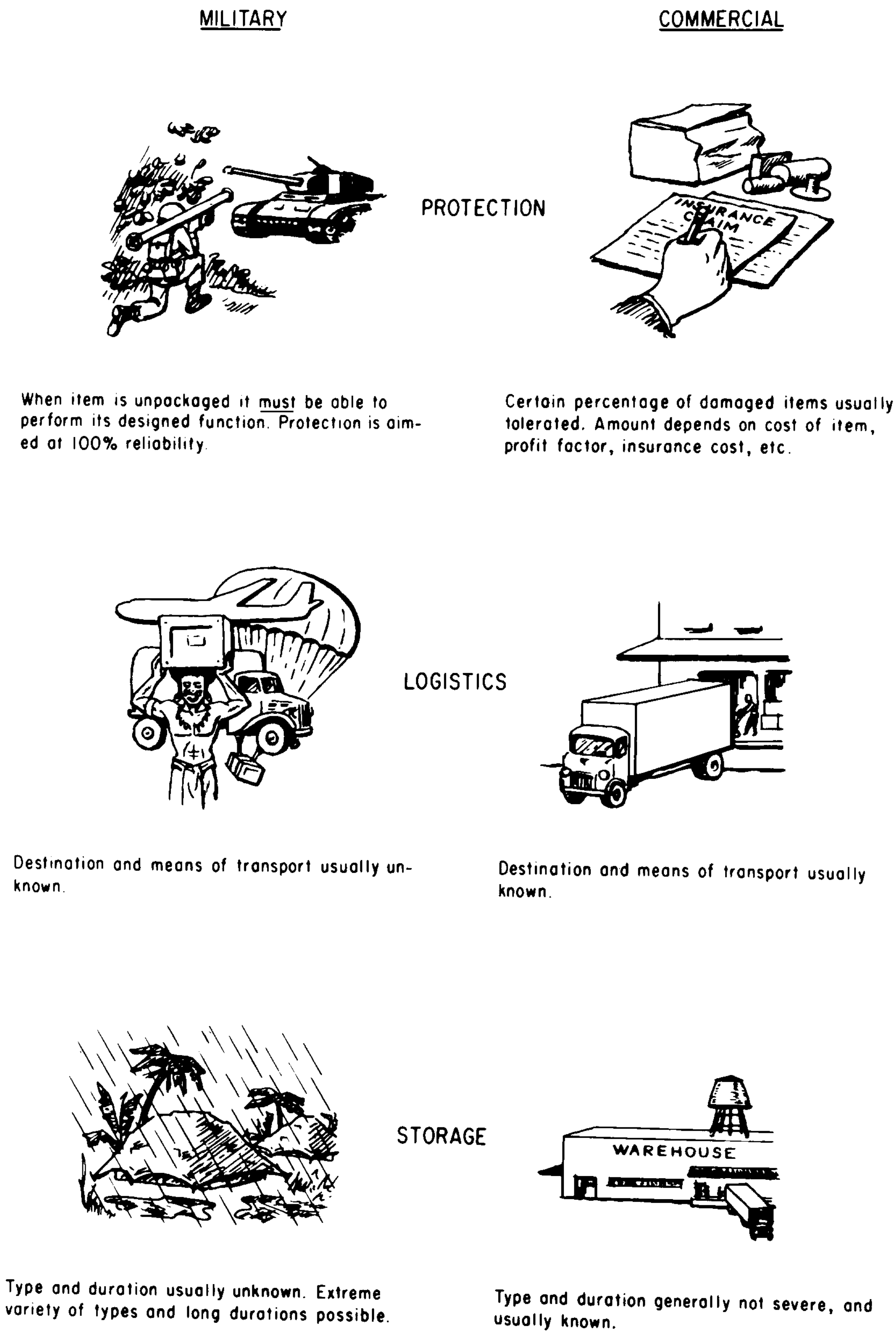


Fig. 1-2. Comparison of Military and Commercial Packaging

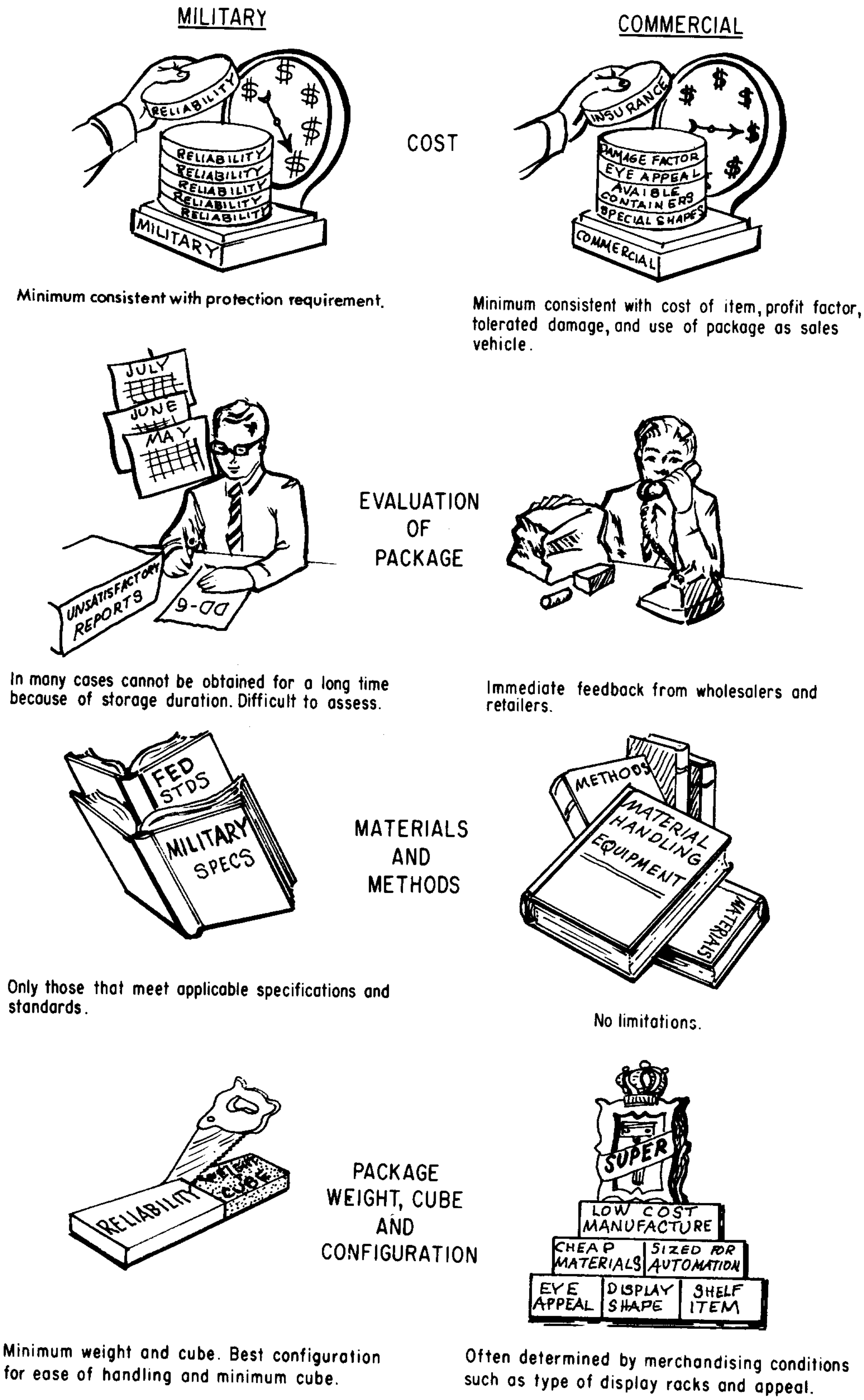


Fig. 1-2. Comparison of Military and Commercial Packaging (Cont.)

CHAPTER 2

FUNDAMENTALS OF PACKAGING DESIGN

2-1 PACKAGING ENGINEERING PRINCIPLES

Main packaging objectives of the military were reviewed in Chapter 1. The task of meeting those objectives through package design can be briefly restated as follows: Select the best possible approach to achieve a high degree of packaging protection with economy, uniformity, and efficiency. This chapter discusses the fundamentals that govern the design of packaging to meet these objectives.

2-2 PACKAGING ENGINEERING PROCEDURES

The procedures which follow should be adhered to in order to assure the highest practical standards of packaging protection. Although these procedures will be useful in serving as guidelines to packaging design, it will remain for the packaging engineer to select the most suitable and appropriate methods and materials for each particular application. Consequently, the presented sequence of step-by-step procedures is only a suggested approach and will vary according to the particular requirements of the project.

a. Obtain item drawings, specifications, procurement documents, and the actual hardware item whenever possible.

b. Determine item characteristics (size, weight, configuration, chemical characteristics, etc.).

c. Determine the level of protection required.

d. Determine unit package quantities and intermediate package quantities.

e. Establish method of preservation.

f. Establish method of cleaning, drying, and preserving.

g. Select unit and intermediate package materials.

h. Determine barrier and cushioning requirements.

i. Select an exterior container or design special containers or pallets when required.

j. Establish marking requirements.

k. Prepare packaging documents which describe these listed requirements along with sketches or drawings, when necessary, to describe special bracing, cushioning, or container designs.

2-3 SOURCES OF DATA

Ideally, the critical packaging features of an item are identified during the design of the item. If the packaging engineer is consulted during this phase, he can often suggest changes that will in no way compromise the effectiveness of the item but will greatly facilitate the resolution of packaging problems.

Whenever there is no opportunity for consultation during the design phase of the item, the packaging engineer should have, for his guidance, both the item and the accompanying prints from which the item was developed. Prints will point out, for example, fragility problems not readily apparent during visual inspection. It should be recognized that prints are often the only source of information to the packaging design engineer and his ability to read them in terms of packaging requirements is essential. Close coordination between the manufacturer and the packaging engineer is always beneficial in establishing packaging criteria.

2-4 ITEM CHARACTERISTICS

It is desirable to minimize the number of packaging methods and the types and sizes of packages. One method of simplifying and standardizing packaging is by grouping items which are dissimilar in their function but which are, for packaging purposes, similar in their chemical and physical properties–e.g., nails-screws, radio tubes-light bulbs, air filters-oil filters. This method, however, cannot be extended to all items because of peculiar weight, configuration, fragility, and other

characteristics–e.g., engine-transmission which have configuration differences, radio set-telephone which have different fragilities. This area is dealt with in more depth in Chapter 3.

The following paragraphs briefly discuss three types of item characteristics that are frequently critical in determining packaging methods and materials:

(1) Susceptibility to chemical deterioration

(2) Susceptibility to physical damage

(3) Maximum disassembly and breakdown allowable.

Of equal importance in determining the packaging methods and materials to be used are logistical considerations, which are discussed in par. 2-6. Chapter 3 will review item characteristics in greater detail.

2-4.1 SUSCEPTIBILITY TO CHEMICAL DETERIORATION AND PHYSICAL DAMAGE

There are two considerations concerning the item to be packaged that are of major importance in packaging. One consideration is that some items can be destroyed by chemical action such as rust, stain, and decomposition. The other is that some items can be destroyed by physical damage such as abrasion, shock, and vibration.

Chemical damage is usually prevented by using preservative compounds, atmosphere control, or other means that will combat conditions that contribute to deterioration. Physical damage is usually prevented through the use of cushioning, blocking, and bracing. These two types of vulnerability are not always separate. In combatting physical damage, it is also necessary to consider deterioration. For example, cushioning materials selected must not add to further chemical deterioration of items vulnerable to chemical change.

2-4.2 FEASIBILITY OF DISASSEMBLY

The degree of disassembly an item can undergo will affect the overall package dimensions and the degree of protection required. Cube reduction is a particular advantage that may be gained through disassembly. (See Fig. 2-1 for an example of a disassembled rack that saves both space and costs.) Excess weight or cube–because of oversize containers, lost space, and unnecessary cushioning and blocking–not only constitute overpackaging but also increase storage and shipping costs. AR 740-17 (Ref. 1) outlines the factors that determine overpackaging.

In addition to cube reduction, disassembly may offer, in all or in part, a reduction or simplification of the protection needed against physical and chemical damage. Whereas before disassembly the complete unit may have required a cushioning level suitable for its most delicate parts, after disassembly each part will require cushioning only to its own level of fragility. In the same manner, disassembled items may offer less of a preservation problem than when they are in the assembled state. However, the cost and difficulty involved in disassembly and reassembly, as well as the space and time involved in storing removed equipment, must be considered (Refs. 3, 4).

2-4.3 OTHER ITEM CHARACTERISTICS

Although function, end use, and ultimate destination of an item do not usually play a major role in the selection of packaging procedures or materials, these and other characteristics may become critical design factors for particular items. The following listing is intended only as a sample of the types of factors, other than the primary chemical and physical properties of the item, that may become critical:

a. Requirement for a high degree of cleanliness. The cleanliness requirement applies also to the packaging materials in contact with the item.

b. Requirement for surveillance of item throughout the manufacturer-to-user sequence. Methods of monitoring pressure and electrical continuity without opening the container may be necessary.

c. Requirement for item orientation within a container to facilitate complete checkout without removal of the unit from its suspension frame.

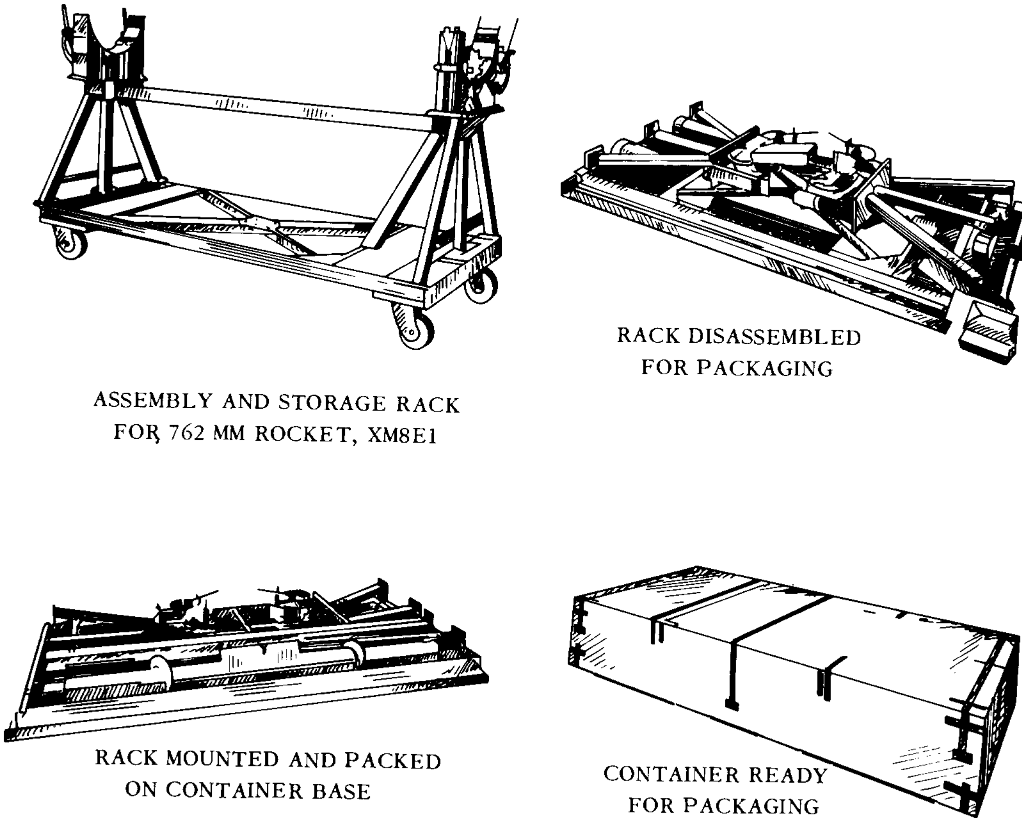
d. Requirement for the securing of heavy items within their containers in the same manner that they will be secured when in use.

e. Requirement that items destined for sites with little depreservation facilities be preserved with compounds that need not be removed.

f. Requirement for reuse of the container.

2-5 ADDITIONAL FACTORS AFFECTING PACKAGING DESIGN

Many questions of package design can be resolved only by a study of the military characteristics and the manufacturer-to-user sequence of an item. Factors such as overall simplicity, cost, ease of maintenance, and optimum use of available space in storage all bear on which package design is best for a particular situa-



NOTE: A SAVINGS OF $10,481 IN COST AND 19,572 CUBIC FEET IN DISPLACEMENT WAS REALIZED BY SHIPPING 34 RACKS DISASSEMBLED.

Fig. 2-1. Disassembly–a Means of Saving Cube[2]

tion. Human factors considerations may also have an important bearing because, where possible, packages should not exceed weights and sizes that can be handled with ease and safety.

For the best possible design, the packaging engineer needs full information on the requirements that the package is expected to fulfill; i.e., he must know as much as possible about the logistical plans, distribution, and end use of the item. Generally, the more that is known about the planned logistic, distribution, and end use of an item; the more the package can be tailored to the needs of the item. When little is known about these requirements, the package must provide protection for world-wide use with all possible types of transportation and storage.

2-6 LOGISTICAL CONSIDERATIONS

From the logistical plans, the packaging engineer can often learn the anticipated type of storage and duration, the quantity and rate of issue; and, in some cases, the mode of transportation to be used. The importance of ready access to, and removal of, contents is another requirement which may be predetermined. Refer to Chapters 14 and 17.

2-6.1 TRANSPORTATION

When it is known that a package will always move by one mode of transportation, then the package can be designed accordingly because the packaging engineer will know the shock and vibration environment. If such is the case, sometimes even delicate items may be cush-

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ioned and shipped in lightweight cartons or pallets directly from a manufacturer to a using site if the transport system is appropriate. However, because this is rarely the case, an alternate package design must always be prepared that is suitable for all types of transportation.

2-6.2 HANDLING

Because the packaging engineer rarely knows the handling system to the point of use, he must design a package that will protect the item against the most severe hazards that packages are likely to encounter.

Methods of handling and loading–especially for large, heavy items–should also be anticipated at the time of design. Although wheeled items present few problems because they can be rolled aboard carriers and lashed in place, other large items may require casters, dollies, and special skids.

Packages must be designed strong enough to withstand handling forces without being distorted. Packaged items may be moved by fork-lift trucks, dollies, or rollers. All of these methods provide support for only a portion of the pack with a large overhang often resulting. For items moved by slings and grab hooks, tremendous pressures are often exerted against the top corners and edges of the upper sides of the pack.

2-6.3 STORAGE

The U.S. Army Weapons Command publication, *Listing of Requirements for Missile Container Design* (Ref. 5), and TM 9-1300-206, *Care, Handling, Preservation and Destruction of Ammunition* (Ref. 6), list provisions for the safe storage of packaged items. Coverage includes storage, conservation, stability, and safety. Fig. 2-2 illustrates desirable features for storing packaged items. Refer to Chapter 10.

2-6.4 HUMAN FACTORS CONSIDERATIONS

Although human factors considerations are primarily item design considerations, they may be involved in package design. If economically feasible, packages should be designed so they do not exceed the minimum and maximum dimensions that personnel can carry or disassemble with ease.

For information on this handling consideration, refer to *Human Engineering Guide to Equipment Design,* Chapter 11 (Ref. 7) which gives human body dimensions, range of movement of body members, muscle strength, etc. Fig. 2-3 illustrates the type of information available. Other human factors criteria that may be relevant are provided in TM 21-61 (Ref. 8), and AMCP 706-134, *Maintainability Guide for Design* (Ref. 9). Specific measurements for human factors can be found in MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities* (Ref. 12), and HEL Standard S-6-66, *Human Factors Engineering Design Standard for Wheeled Vehicles* (Ref. 13).

2-6.5 WEIGHT AND CUBE

Tare weight and cube are measures of shipping and storage costs. To achieve the best use of space in all types of transportation and storage at the least cost, container design should take account of weight and cube (Fig. 2-4) concurrently with end use, protection, and cost.

2-6.6 DISTRIBUTION

2-6.6.1 Pattern

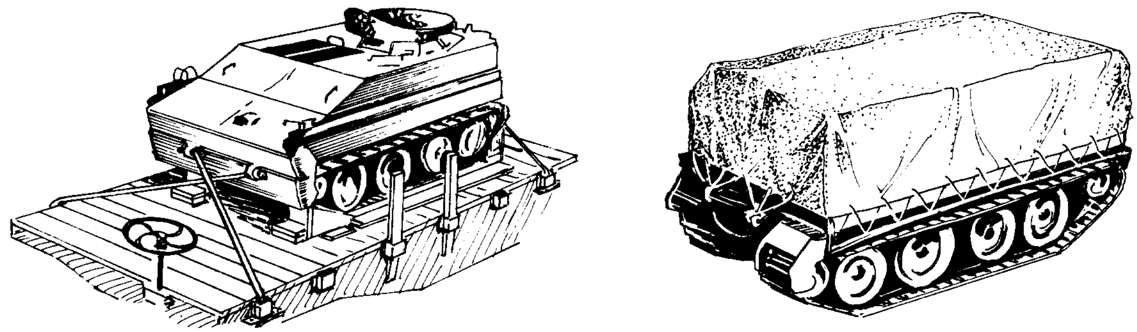
A lack of knowledge of the distribution pattern for a particular item at the time of package design is probably the major contributing factor in military packaging costs. Packaging for limited distribution patterns can, therefore, result in cost savings. These savings, however, are worthless if the assumption of limited distribution is erroneous and the protection of the packaged item is impaired as a result.

2-6.6.2 Unit Quantity

The unit quantity to be used in a package is another important distribution consideration. Ideally, it should be the smallest quantity normally distributed to the ultimate user. Unit quantities smaller that this usually result in additional packaging, storage, and shipping costs because of the extra operations and materials involved, and the resultant increase in weight and cube of the exterior container. Unit quantities larger than those desired by the ultimate user can result in intermediate redistribution and packaging costs, as well as deterioration of those items remaining in the opened unit pack after some items have been removed for use.

2-6.7 DESTINATION

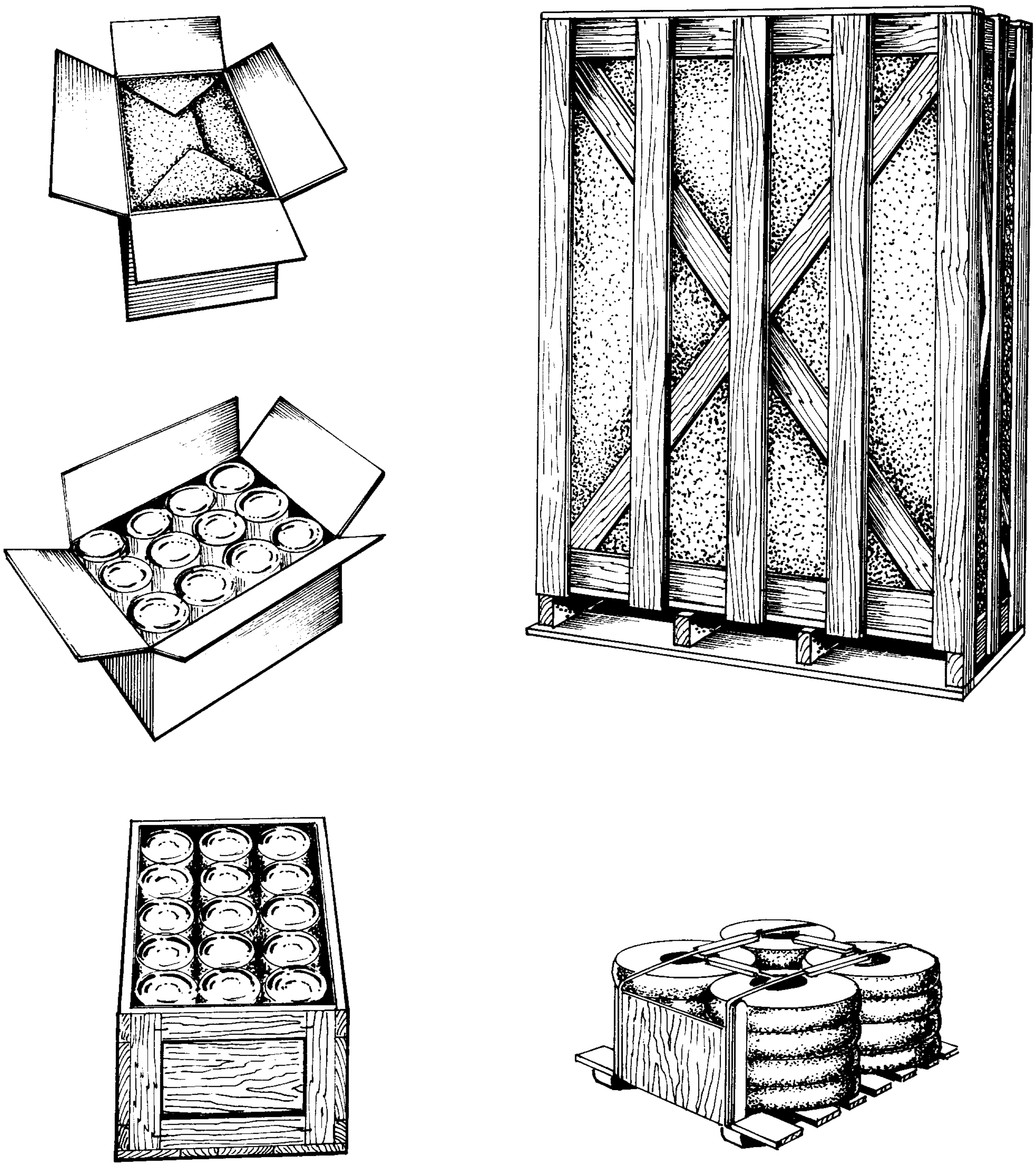
Shipping containers, in particular, will vary depending on whether the destination is domestic or overseas. The various protection levels, as described in par. 1-3.2, will determine the type of container selected.



(A) BLOCKING AND TIE-DOWN

(B) EXTERIOR COVERING AND PROTECTION

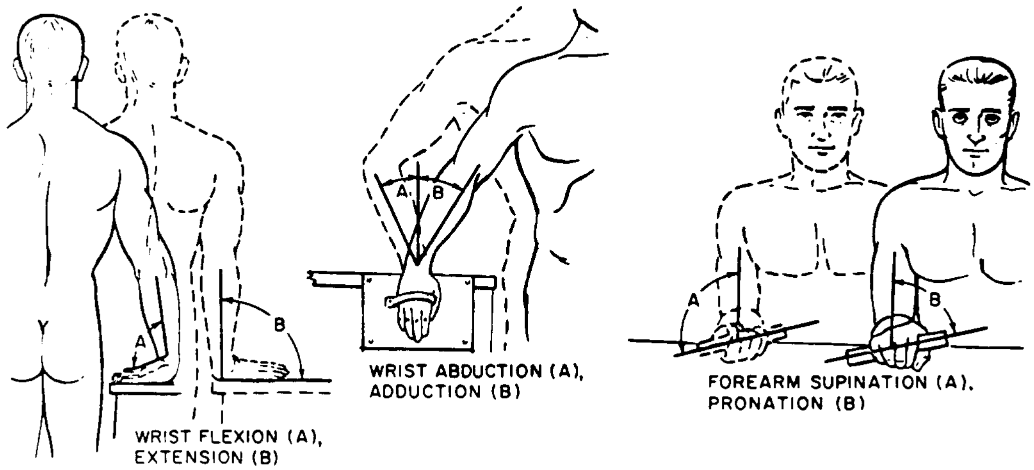
Fig. 2-2. Storage Factors



(C) CONTAINER STRENGTH REQUIREMENTS

(D) EXTERIOR SUPPORT AND HANDLING REQUIREMENTS

Fig. 2-2. Storage Factors (Cont.)



MAXIMUM FORCE THAT CAN BE EXERTED IN LIFTING[1] BY MALE AIR FORCE PERSONNEL

Type of lift	Percentiles (lb) 5th	50th	95th	S.D.*
Backlift[2]	375	520	665	90
Leglift[3]	1010	1480	1950	290

[1] Two-handed vertical pull on a horizontal bar about 28 in. above floor level.

[2] Legs are straight and the back is bent and then straightened for the lift.
[3] Back is straight and the legs are bent and then straightened for the lift.

MAXIMUM WEIGHT THAT CAN BE LIFTED[1] TO VARIOUS HEIGHTS BY MALE AIR FORCE PERSONNEL

Height lifted (ft)	Percentiles (lb) 5th	50th	95th	S.D.*
One	142	231	301	47
Two	139	193	259	40
Three	77	119	172	31
Four	55	81	112	19
Five	36	58	83	16

[1] Subjects lifted a maximally weighted ammunition case (25½ X 10¾ X 6 in.) from the floor and placed it on platforms of various heights.

MAXIMUM FORCE THAT CAN BE EXERTED IN BACKLIFT[1] BY MALE BRITISH CIVILIAN POPULATIONS

Population	Percentiles (lb) 5th	50th	95th	S.D.*
Students	271	367	643	58.9
Employed	251	363	474	67.7
Unemployed	214	315	415	60.8

[1] Two-handed vertical pull on a horizontal bar about 28 in. above floor level.

MAXIMUM FORCE THAT CAN BE EXERTED IN BACKLIFT[1] BY FEMALE BRITISH CIVILIAN POPULATIONS

Population	Percentiles (lb) 5th	50th	95th	S.D.*
College students	160	216	272	34.4
Factory workers				
employed	119	183	247	38.8
unemployed	101	165	229	39.2

[1] Two-handed vertical pull on a horizontal bar about 28 in. above floor level.

*S.D. — Standard Deviation

Fig. 2-3. Human Factors Considerations[7]

2-6.8 STATUTORY LIMITATIONS

Freight and other regulations are extremely important because they govern the construction of shipping containers and set forth the procedures for loading and shipping the materials within common carriers. All shipping containers must comply with such regulations and other limitations discussed in Chapters 17 and 18.

2-7 PACKAGING, PACKING, AND SHIPPING COSTS

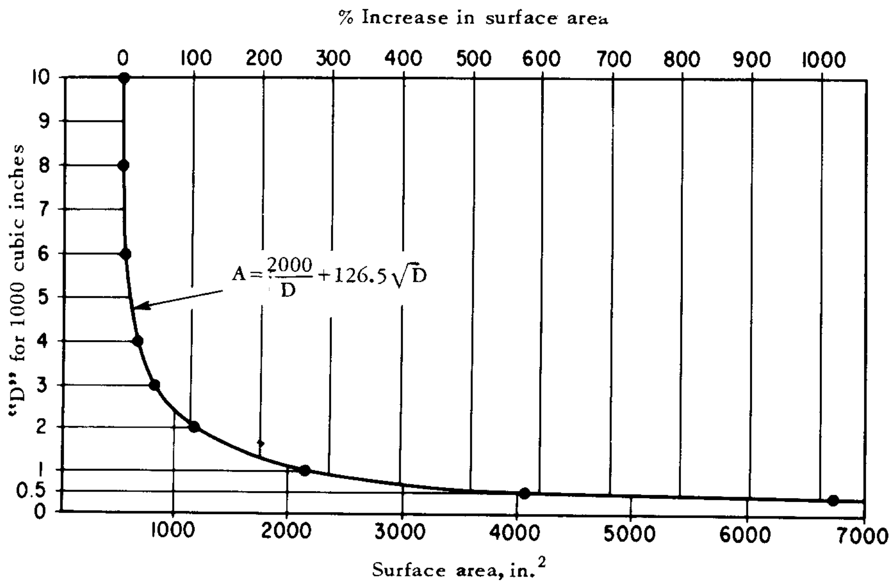
Although protection is the prime consideration in military packaging and packing, packaging engineers are expected to choose the least costly of acceptable methods promising the required protection. When only one method meets all the requirements, cost can still be minimized through design. Cost is understood to include all factors from manufacture to end item use.

All costs affected or created by package design are pertinent to engineering considerations. Personnel concerned with estimating packaging costs are referred to the documents: *Packaging Cost Manual*-TB 38-275; and *Storage and Shipment of Supplies and Equipment, Excessive Packaging*-AR 740-17. Although these documents do not give rules for achieving packaging economy, they can be used as yardsticks to measure contract prices. Allowance must be made to include costs of items such as indirect labor, administrative costs, insurance, burden on equipment, and a reasonable profit, which the standard excludes.

2-8 TESTING AND INSPECTION

Testing in the design phase is directed toward proving the adequacy of the proposed package or container. Development and testing of packages and containers should begin as soon as possible after initiation of item development.

•IN RECTANGULAR FIGURES A CUBE WILL ALWAYS HAVE THE LEAST SURFACE AREA FOR A GIVEN VOLUME, THEREFORE ANY DEVIATION FROM A CUBICAL FIGURE REQUIRES MORE SURFACE AREA THAN A CUBE FOR THE SAME VOLUME.....



NOTE:

A–SURFACE AREA
D–DIMENSION OF DEPTH
(MAINTAINING 1000 CUBIC INCHES OF VOLUME)

Fig. 2-4. Relationship of Surface Area to Volume

Some of the tests most commonly used in proving design adequacy include: vibration, impact (incline, pendulum, free fall), cyclic exposure, and salt spray. (Refer to Chapter 17.) One or more of these tests are usually applicable to the design of military packages and packs. In many cases the technical activity responsible for design has internal tests and procedures that are applicable to a specific design problem. The documents most generally used for test guidance are MIL-STD-1186, MIL-P-116, and Federal Test Method Standard Number 101. Chapter 17 describes testing in greater detail.

After packages and containers are selected and in use, information on their performance can be obtained by a continuing inspection of items in storage by depot storage personnel and by the packaging engineer's analysis of damage reports or notices of improper shipments. DD Form 6 (Report of Damaged or Improper Shipment) can be an effective tool if geared to quick corrective action. Improper handling practices and misinterpretation of specifications, as well as inadequate packaging methods and materials, may be revealed in this way. Requirements for the routing of DD Form 6 are provided in AR 700-58 (Ref. 10).

2-9 AUTHORIZED AND APPROVED METHODS AND MATERIALS

By choosing authorized and approved methods and materials already covered by specifications, the packaging engineer can often reduce the engineering effort required to produce packaging data. This restricting of packaging methods and materials also reduces requirements for testing and documentation.

By depending on factors such as item characteristics, item distribution, and the supply system, the engineering effort required for packaging items covered by specifications is largely limited to modifying or adding to these authorized methods rather than establishing new procedures for each new item to be packaged. The application of authorized methods limits the number of methods and materials used for a great variety of items. The known performance of these methods, when applied under specified controls, eliminates costly and time-consuming tests. Besides reducing engineering effort and testing, the use of a limited number of methods and materials reduces documentation because basic packaging instructions can apply to a group of items rather than just to a single item.

2-9.1 SPECIAL REQUIREMENTS

Occasionally, the packaging engineer will not be able to follow specified methods or use specified materials. For example, large or complex items such as vehicles, artillery, and missiles often cannot be processed by a single method or submethod specified by MIL-P-116 (Ref. 11). This may also be the case when packaging a kit combining a number of parts of various complexities requiring different degrees of protection. Also, in certain cases, a particular material or combination of materials, or an automatic packaging process may provide adequate protection and is more suitable than MIL-P-116. But even when the procedure differs from MIL-P-116, the packaging engineer must give preference to materials covered by existing Military or Federal Specifications or Standards, and those which meet statutory limitations.

2-9.2 NEW METHODS AND MATERIALS

The existence of specifications and standards does not mean that the packaging engineer is strictly limited in his choice of methods and materials. Approved methods and materials are preferred, as has been emphasized, because they reduce the design effort. However, there may be other overriding factors and the packaging engineer should be on the alert to review packaging requirements in the light of any new application of practices and materials. Certain designs may lend themselves to plant economics in packaging operations; others may make field service surveillance and maintenance simpler; or a particular design may offer especially rapid access to the item by the user. Fig. 2-5 contains examples of new methods and materials which resulted in smaller, more economical containers.

2-10 SUMMARY OF PACKAGING AND PACK DESIGN

Fig. 2-6 shows the basic packaging steps and the sequence in which they are normally carried out. Often, because of the nature of an item and its distribution requirements, not all of these steps are required. For example, a preservative may not be needed, or the unit pack might also serve as the packing.

The various materials and methods that can be used in carrying out each of the basic steps are well documented in specifications and standards. It is the task of the military packaging engineer to select, in confor-

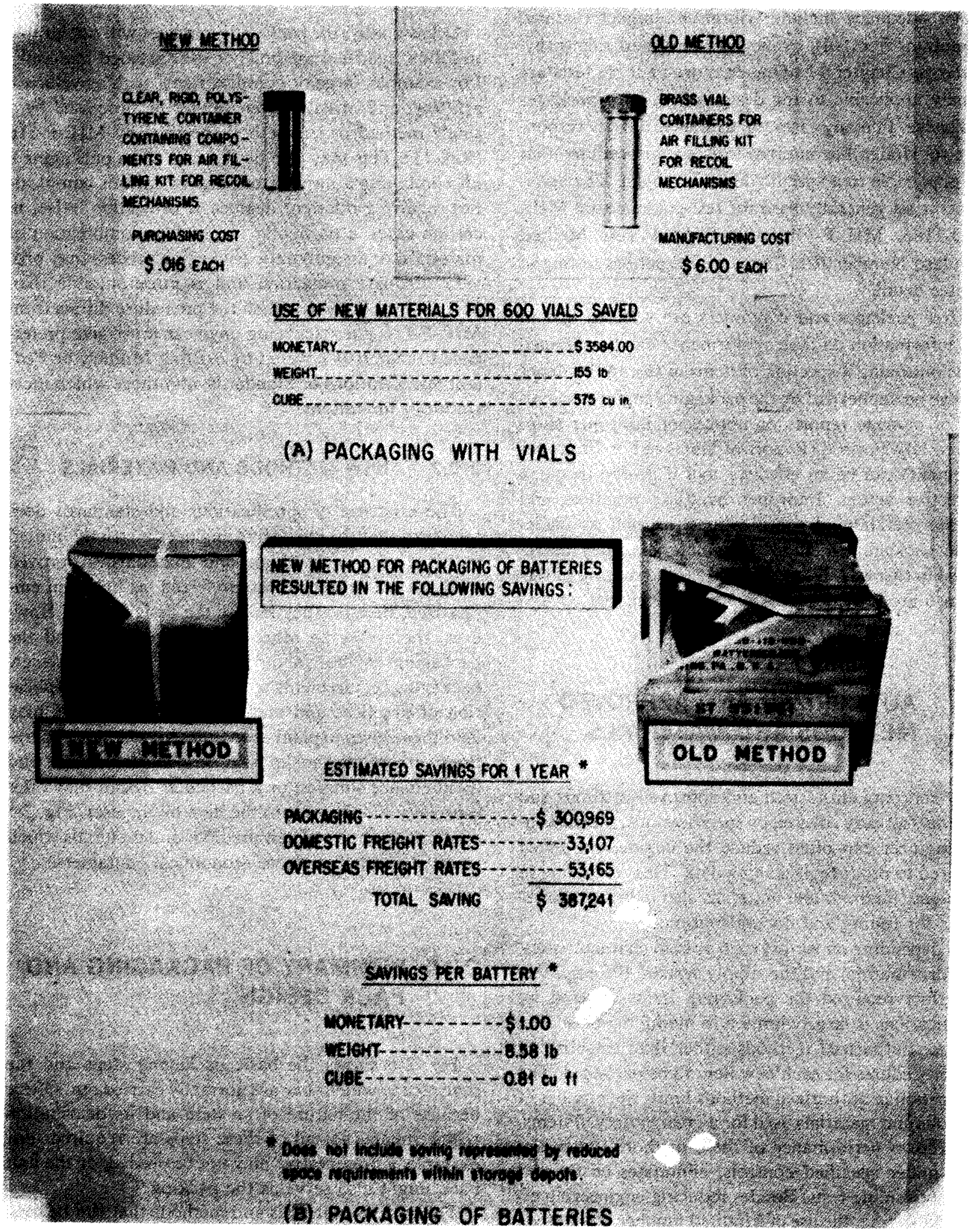


Fig. 2-5. Use of New Methods and Materials in Packaging[2]

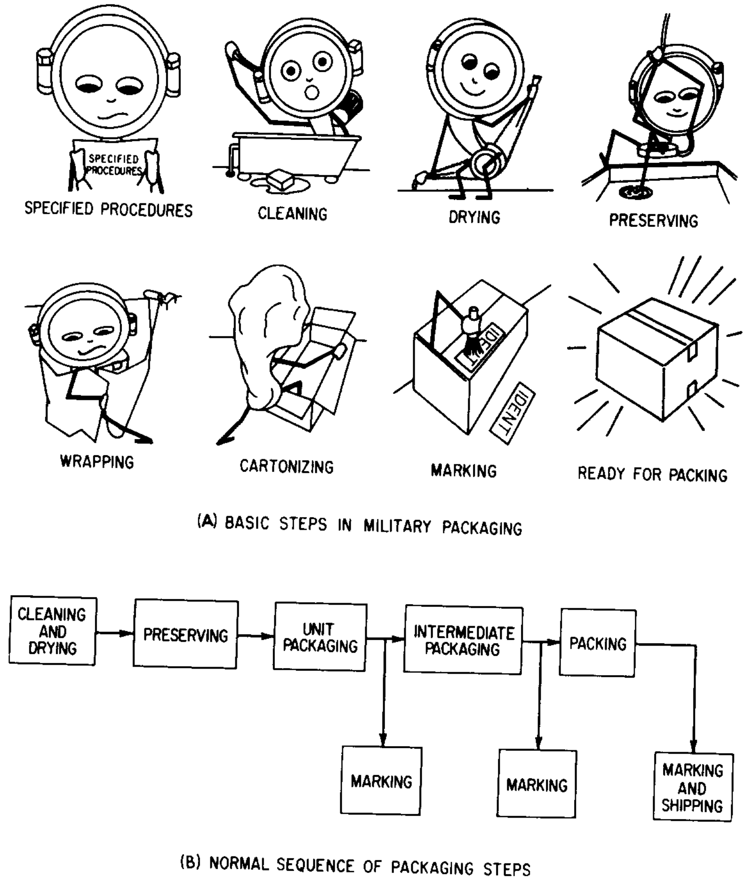


Fig. 2-6. Basic Steps in Military Packaging and Their Normal Sequence

mance with these specifications and standards, the best materials and methods for each particular application.

The basic governing specification for cleaning, drying, preserving, and unit packaging is MIL-P-116. Detailed information to aid in their selection is given in Chapters 5, 6, and 7. Cleaning and drying methods are covered in Chapter 5, preservatives in Chapter 6, and methods of preservation in Chapter 7. The allowable methods and materials specified in MIL-P-116 are summarized in Table 7-1.

Numerous specifications exist which cover boxes, bags, crates, etc., and can be used for selecting intermediate packaging and packing containers. Selection of these items is covered in Chapters 8 through 11.

REFERENCES

1. AR 740-17, *Storage and Shipment of Supplies and Equipment, Excessive Packaging.*
2. American Ordnance Association, *The State of the Art of Packaging,* AOA Technical Division Rept., November 1961.
3. AMCR 746-2, *Marking and Packaging of Supplies and Equipment.*
4. Joint Military Packaging Training Center, *Course Outline,* Aberdeen Proving Ground, Maryland, 1962.
5. *Listing of Requirements for Missile Container Design,* U.S. Army Weapons Command, Research and Engineering Division, Watervliet Arsenal, New York, 1962.
6. TM 9-1300-206, *Care, Handling, Preservation and Destruction of Ammunition.*
7. C. T. Morgan, et al., *Human Engineering Guide to Equipment Design,* McGraw-Hill Book Company, Inc., New York, 1963.
8. TM 21-61, *Manual of Standard Practice for Human Factors in Military Vehicle Design.*

9. AMCP 706-134, Engineering Design Handbook, *Maintainability Guide for Design.*

10. AR 700-58, *Logistics (General), Report of Damaged or Improper Shipment.*

11. MIL-P-116, *Preservation, Methods of.*

12. MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities.*

13. HEL Standard S-6-66, *Human Factors Engineering Design Standard for Wheeled Vehicles,* Human Engineering Laboratories, Aberdeen Proving Ground, Aberdeen, Maryland, September 1966.

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Ernest J. McCormick, *Human Engineering,* McGraw-Hill Book Co., New York, 1957.

E. Wesley, et al., *Human Engineering Guide for Equipment Designers,* University of California Press, Berkeley, California 94720, 1964.

CHAPTER 3

ITEM CHARACTERISTICS

Packaging decisions, methods, and materials always hinge on the most critical feature of the item being packaged. This chapter discusses the chemical and physical properties of military items that most often determine packaging requirements. Although individual item characteristics are described separately, they are inter-related. Usually, no one particular item characteristic is directly related to a specific packaging method or material. When item characteristics are analyzed and grouped, a pattern may be distinguished that can be related to specific packaging methods and materials.

3-1 LIKE ITEMS

The packaging of like items in the same way can usually be accomplished by applying sound technical and engineering principles to each design effort. The disparity of design among military items precludes their classification into groups by function or nomenclature, and requires individual treatment for each item. The primary cause of difficulty in determining true likeness is that likeness is not always a function of composition and configuration only, but often depends also on factors such as end use and item distribution.

The packaging engineer may, for general guidance, use such compilations at SB 38-100 (Ref. 1) which lists materials and equipment for which stock numbers have been assigned and which are commonly used, and TM 38-230-2 (Ref. 2) which presents methods that have been successfully used to protect materiel from physical damage and deterioration. When such guidance is used it must be determined that the item is in fact similar. Adaptation of similar packaging for like items should not be made until it is determined that the item is similar in all important respects.

3-2 STANDARD AND NONSTANDARD ITEMS

3-2.1 STANDARD GROUP ITEMS

Fig. 3-1 illustrates an electrical relay which is considered to be a typical standard item because it can be packaged using standard military materials and methods and requires no special instructions. Items falling into this classification will be of a type for which complete packaging detail can be expressed without the use of drawings, sketches, figures, or narrative which are peculiar to a single or limited number of such items. Standard group items are those items which have the same physical and chemical characteristics as shown in Fig. 3-3.

3-2.2 NONSTANDARD GROUP ITEMS

Fig. 3-2 illustrates a surge tank, which is considered to be a typical nonstandard item because of its size,

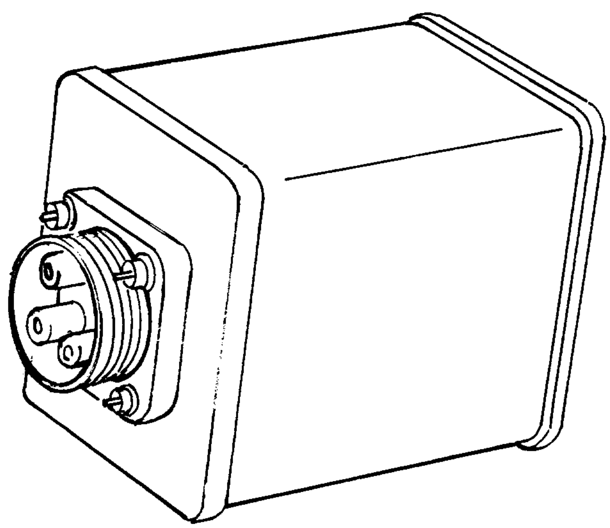

Fig. 3-1. Electrical Relay, a Typical Standard Item

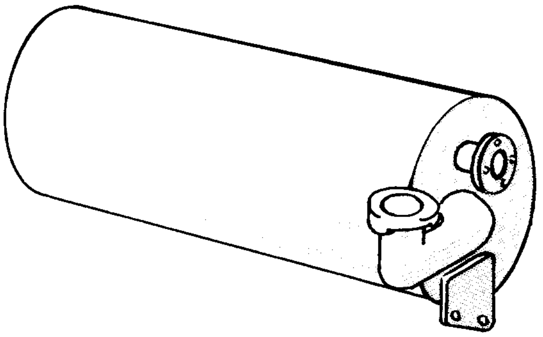

Fig. 3-2. Surge Tank, a Typical Nonstandard Item

weight, unusual configuration, and its requirement for special packaging materials and instructions. Nonstandard group items are items that have characteristics which prevent the use of packaging standards in prescribing the packaging requirements. Such items–because of peculiar weight, configuration, complexity, fragility, or other considerations–require packaging data which are applicable only to an individual type of item, or a limited group of items. Generally, an item will be considered as nonstandard if (1) drawings, sketches, or illustrations are required to control the dimensions or positioning of the package or the item within the package, or (2) nondrawing-type instructions identified with the item are required.

3-3 PACKAGING REQUIREMENTS

Basic characteristics of the item to be considered at the time of package design are as stated in the paragraphs which follow. These characteristics can be used in preliminary design analysis to determine the following major packaging requirements:

a. Required protection against deterioration

b. Required protection against shock and vibration

c. Required degree of disassembly

d. Required points for supporting, clamping, and holding the item in the container.

3-4 CATEGORIZING ITEM CHARACTERISTICS

3-4.1 OBJECTIVES

There are four main objectives in grouping item characteristics:

(1) To package in a similar manner items that have the same or similar chemical and physical characteristics

(2) To reduce the number of packaging materials used

(3) To reduce the costs of producing engineering data

(4) To reduce administrative time and costs.

An example of how item characteristics have been categorized to meet these objectives and form the basis of an efficient, economical packaging system is the system defined in MIL-STD-647 (Ref. 3) and described in par. 3-4.2.

3-4.2 PRE-ENGINEERING PACKAGING DATA

Two types of items may be distinguished for packaging purposes: (1) those that can be packaged by pre-engineered packaging data; and (2) those that must have specifically engineered packaging data. Item characteristics are primarily intended to provide means of grouping large numbers of items by their chemical and physical similarities so that packaging may be accomplished with the minimum of engineering effort. By providing criteria for defining and identifying critical item characteristics, a means is provided for comparing items to these criteria and placing all items having the same characteristics in a single group.

MIL-STD-647 (Ref. 3) establishes certain criteria and requirements for using a limited number of the same materials and methods for a great number and variety of items. Criteria and instructions for converting the general data, applicable to a group of items, to data for specific items are given in this handbook. The five chemical and physical characteristics selected for this system are:

(1) Surface chemistry

(2) Surface, mechanical

(3) Configuration-complexity

(4) Flexibility-fragility

(5) Size and weight.

These five primary categories of item characteristics and their divisions are intended to identify specific characteristics that, when added together, will permit a single method of packaging to be used on all items having the same category symbols. Most of the categories and divisions have only a general relationship to any specific packaging method. Fig. 3-3 illustrates the categories, divisions, and symbols of this method of grouping item characteristics.

(This chart is for information only. See Ref. 3 for categorizing)

SURFACE CHEMISTRY	
SURFACE CHEMISTRY IS THE CHEMICAL NATURE OF THE MATERIAL THAT IS EXPOSED ON THE SURFACE OF THE ITEM TO THE ATMOSPHERE, I.E., IRON, ALUMINUM, PLASTIC, GLASS, ETC. THE SURFACE CHEMISTRY OF AN ITEM IS THE MOST INFLUENTIAL FACTOR IN DETERMINING WHETHER A PRESERVATIVE MAY BE USED, WHETHER ONE IS NEEDED AND THE TYPE.	
DIVISIONS OF SURFACE CHEMISTRY	
METALLIC FERROUS BARE: IRON, STEEL AND THEIR ALLOYS EXCEPT STAINLESS STEEL (SEE "C" BELOW).	SYMBOL A
METALLIC FERROUS, PARTIALLY PLATED, PAINTED OR COATED: INCLUDES IRON, STEEL AND THEIR ALLOYS EXCEPT STAINLESS STEEL (SEE "C" BELOW).	SYMBOL B
METALLIC, NON-FERROUS, BARE, PARTIALLY PLATED, PAINTED OR COATED—ALL COMPLETELY PLATED OR COATED. METALLIC AND STAINLESS STEEL.	SYMBOL C
METALLIC COMPOSITES — COMBINATIONS OF FERROUS AND NON-FERROUS METALS: BARE OR PARTIALLY PLATED, PAINTED OR COATED.	SYMBOL D
COMPLETELY PAINTED ITEMS: INCLUDES ALL METALLICS AND NON-METALLICS.	SYMBOL E
NON-METALLIC COMPOSITE AND NON-COMPOSITE.	SYMBOL F
METALLIC-NON-METALLIC COMPOSITE: BARE OR PARTIALLY PLATED, PAINTED OR COATED.	SYMBOL G
NON-METALLIC SPECIAL: ITEMS NORMALLY CONSIDERED AS NON-CORROSIVE WHICH REQUIRE SPECIAL PROTECTION AND FABRICATED OF RUBBER, WOOD, CANVAS, CORK, PAPER, ETC.	SYMBOL H
METALLIC, NON-METALLIC SPECIAL:	SYMBOL J
NOT ASSIGNED	SYMBOL K

SURFACE MECHANICAL	
SURFACE MECHANICAL IS IN REFERENCE TO THE WORK THAT HAS BEEN PERFORMED ON THE SURFACE AND THE WORK THE SURFACE PERFORMS IN ACCOMPLISHING ITS DESIGN FUNCTION. ITEMS IN THESE CATEGORIES HAVE BEEN PROVIDED WITH A WORKED SURFACE BY MACHINING, GRINDING, LAPPING, HONING, POLISHING, COINING, STAMPING OR OTHER MEANS.	
DIVISIONS OF SURFACE MECHANICAL	
BEARING—OPEN:	SYMBOL 1
BEARING—SEALED:	SYMBOL 2
NON-BEARING—OPEN:	SYMBOL 3
NON-BEARING—SEALED:	SYMBOL 4
AS MANUFACTURED—OPEN METALLIC ONLY:	SYMBOL 5
AS MANUFACTURED—SEALED METALLIC ONLY:	SYMBOL 6
AS MANUFACTURED—NON-METALLIC:	SYMBOL 7
AS MANUFACTURED—COMPOSITE:	SYMBOL 8
POLISHED OR GROUND SURFACES, ABRASION SUSCEPTIBLE:	SYMBOL 9
NOT ASSIGNED	SYMBOL 0

CONFIGURATION & COMPLEXITY	
ITEMS IN THIS CATEGORY HAVE ONE OR MORE OF THE CHARACTERISTICS OF COMPLEXITY AS DESCRIBED IN REFERENCE HANDBOOK AND IN ADDITION HAVE EXTERIOR SURFACES WHICH MEET THE CRITERIA FOR REGULARITY AS DEFINED THEREIN. ITEMS MAY REQUIRE EXTERNAL PRESERVATIVE APPLICATION OR BOTH. GENERALLY, DISSIMILAR PRESERVATIVES WILL BE USED ON THE EXTERIOR AS COMPARED TO THE INTERIOR.	
DIV'S OF CONFIGURATION & COMPLEXITY	
REGULAR—NON-COMPLEX:	SYMBOL A
IRREGULAR—NON-COMPLEX:	SYMBOL B
REGULAR COMPLEX—EXTERNAL PRESERVATION ONLY:	SYMBOL C
IRREGULAR COMPLEX—EXTERNAL PRESERVATION ONLY:	SYMBOL D
REGULAR COMPLEX—INTERNAL PRESERVATION ONLY:	SYMBOL E
IRREGULAR COMPLEX—INTERNAL PRESERVATION ONLY:	SYMBOL F
REGULAR COMPLEX—INTERNAL AND EXTERNAL PRESERVATION:	SYMBOL G
IRREGULAR COMPLEX—INTERNAL AND EXTERNAL PRESERVATION:	SYMBOL H
REGULAR COMPLEX—NO CONTACT PRESERVATION PERMITTED:	SYMBOL J
IRREGULAR COMPLEX—NO CONTACT PRESERVATION PERMITTED:	SYMBOL K

FLEXIBILITY & FRAGILITY	
WHETHER AN ITEM IS RIGID OR FLEXIBLE, FRAGILE OR RUGGED IS AN IMPORTANT ELEMENT OF CONSIDERATION IN THE SELECTION OF PACKAGING METHODS AND MATERIALS. THE USE OF FLEXIBLE BARRIERS AS OPPOSED TO A RIGID CONTAINER; TO USE A STIFFENER OR NOT AND THE DEGREE OF SHOCK ISOLATION REQUIRED IS LARGELY DETERMINED BY CONSIDERATION OF THESE CHARACTERISTICS.	
DIVISIONS OF FLEXIBILITY & FRAGILITY	
RIGID—NON-FRAGILE:	SYMBOL 1
RIGID—FRAGILE:	SYMBOL 2
RIGID—DELICATE:	SYMBOL 3
FLEXIBLE—COILABLE:	SYMBOL 4
FLEXIBLE—NON-COILABLE:	SYMBOL 5
FLEXIBLE—COMPRESSIBLE, DEFORMABLE:	SYMBOL 6
NOT ASSIGNED	SYMBOL 7
NOT ASSIGNED	SYMBOL 8
NOT ASSIGNED	SYMBOL 9
NOT ASSIGNED	SYMBOL 0

SIZE & WEIGHT	
THESE CHARACTERISTICS HAVE LITTLE OR NO INFLUENCE ON THE SELECTION OF METHODS OF PACKAGING INSOFAR AS THE DEGREE OF PRESERVATION PROTECTION IS CONCERNED. SIZE AND WEIGHT, HOWEVER, ARE IMPORTANT FACTORS IN SEPARATING LARGE QUANTITIES OF DISSIMILAR ITEMS INTO GROUPS OF COMPARABLE ITEMS CAPABLE OF BEING PACKAGED BY A SINGLE SUB-METHOD AFTER CONSIDERATION OF ALL OTHER FACTORS.	
DIVISIONS OF SIZE & WEIGHT	
0 LBS. TO AND INCLUDING 0.25 LBS. ONE DIMENSION 1 IN. OR UNDER & NO DIMENSION EXCEEDING 20 IN.:	SYMBOL A
OVER 0.25 LBS. TO AND INCLUDING 0.5 LBS.—ONE DIMENSION 1 IN. OR UNDER & NO DIMENSION EXCEEDING 20 IN.:	SYMBOL B
OVER 0.5 LBS. TO AND INCLUDING 1.0 LBS.—ONE DIMENSION 1 IN. OR UNDER & NO DIMENSION EXCEEDING 20 IN.:	SYMBOL C
OVER 1.0 LBS. TO AND INCLUDING 2.0 LBS.—ONE DIMENSION 1 IN. OR UNDER & NO DIMENSION EXCEEDING 20 IN.:	SYMBOL D
0 LBS. TO AND INCLUDING 0.5 LBS.—ONE DIMENSION 1 IN. OR UNDER & ONE OR MORE DIMENSIONS EXCEEDING 20 IN.:	SYMBOL E
0 LBS. TO AND INCLUDING 0.5 LBS.—EACH DIMENSION EXCEEDING 1 IN.:	SYMBOL F
OVER 0.5 LBS. TO AND INCLUDING 2.0 LBS.—EACH DIMENSION EXCEEDING 1 IN.:	SYMBOL G
OVER 2.0 LBS. TO AND INCLUDING 5.0 LBS.—NO DIMENSIONAL RESTRICTIONS:	SYMBOL H
OVER 5.0 LBS. TO AND INCLUDING 10.0 LBS.—NO DIMENSIONAL RESTRICTIONS:	SYMBOL J
OVER 10.0 LBS.—NO DIMENSIONAL RESTRICTIONS:	SYMBOL K

Fig. 3-3. Standard Item Characteristics: Categories, Divisions, and Symbols

3-4.3 MINIMUM CRITERIA

The study of item characteristics includes the chemical and physical properties, the corrosion prevention requirements, and any special use requirements that might affect the packaging and packing operations. The following item characteristics, which are discussed in pars. 3-4.3.1 through 3-4.3.9 are minimum essentials that must be considered before the packaging requirements of any item can be determined:

a. Vulnerability to chemical deterioration
b. Vulnerability to physical damage
c. Strength and fragility
d. Type of load
e. Configuration
f. Size and weight
g. Nature of the item
h. Relation of item design to package
i. Compatibility of materials
j. Cost of item.

These item characteristics are discussed separately, in the order listed, although they would be grouped for practical use in devising a packaging system.

3-4.3.1 Vulnerability to Chemical Deterioration

Depending on the chemical nature of the surfaces exposed to the atmospheric environment, items will differ in their vulnerability to, and rate of, deterioration. An all-ferrous item (steel or iron) requires different preservation treatment than a nonferrous (e.g., copper, aluminum) or composite item. Similarly, when a ferrous item has been completely painted or plated, the surface chemistry of the item has been changed to that of the material used for treating the surface. For example, preservation treatment for the clad metals and clad electrical contact materials would depend on the characteristics of the outer surface of the items.

Table 3-1 lists four main categories of materials or surfaces that may require different preservation methods and materials. Fig. 3-4 illustrates common deterioration factors that affect organic and inorganic materials.

3-4.3.2 Vulnerability to Physical Damage

3-4.3.2.1 Shock

The resistance of an item to shock constitutes its ability to withstand impact without damage. The maximum amount of rough handling the item can with-

TABLE 3-1
CATEGORIES OF ITEMS DIFFERING IN VULNERABILITY TO DETERIORATION

A. Inorganic Materials
- (1) Metals and Alloys
  - (a) Ferrous
  - (b) Nonferrous
- (2) Platings
  - (a) Tinplate
  - (b) Terneplate
  - (c) Charcoal Plate
  - (d) Coke Plate
- (3) Coatings
  - (a) Oxide
  - (b) Phosphate
  - (c) Sulfide
  - (d) Vitreous
  - (e) Plastic
- (4) Nonmetals

B. Organic Materials
- (1) Rubber
- (2) Plastics
- (3) Oils and Greases
- (4) Wood
- (5) Fabric

C. Surfaces Requiring Preservation
- (1) Ferrous Metals and Alloys
- (2) Critical Surfaces

D. Surfaces Not Requiring Preservation
- (1) Noncritical and Nonferrous Surfaces
- (2) Plated, Coated, Primed, and Painted Surfaces

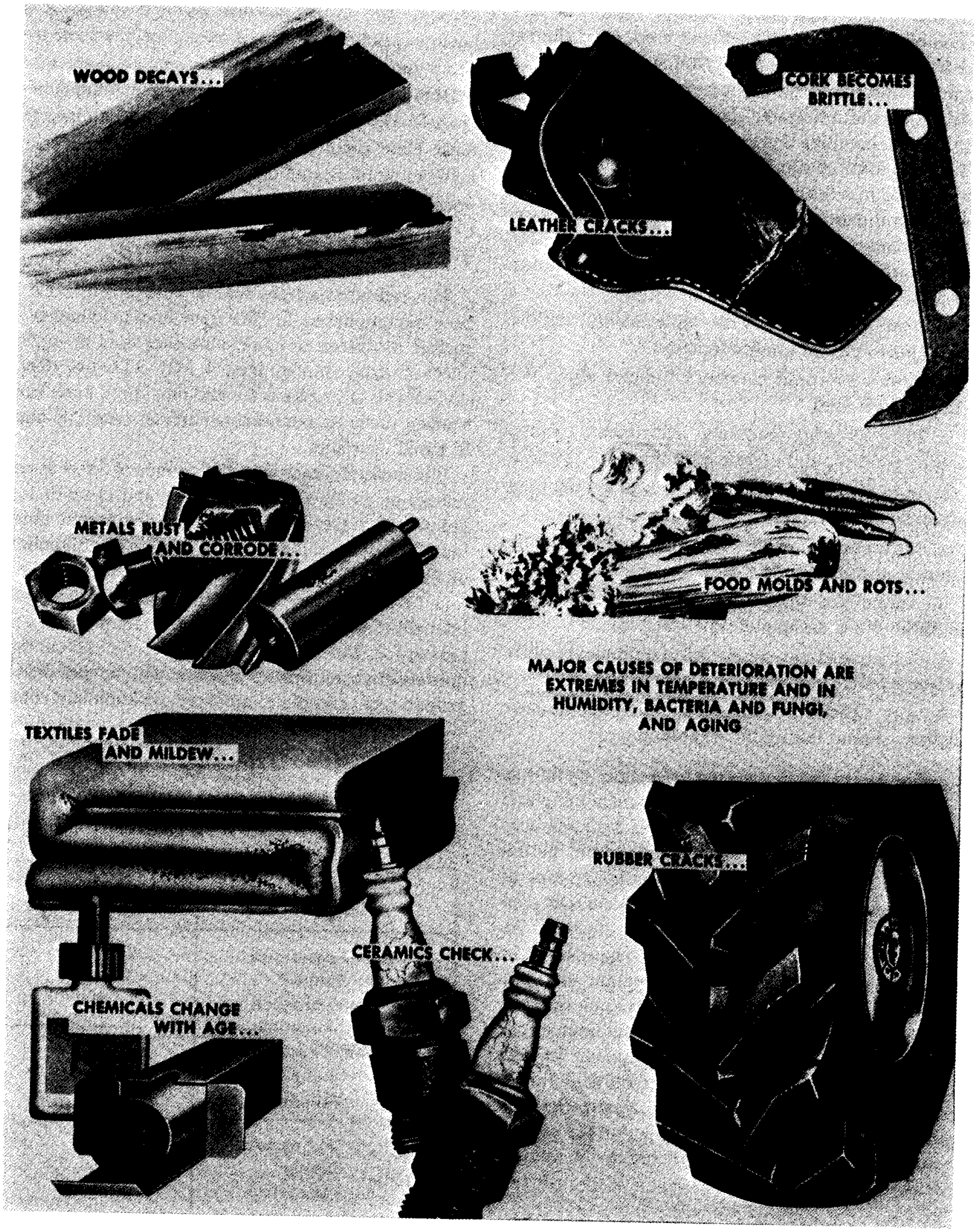

Fig. 3-4. Deterioration Factors[6]

stand, and still function properly, determines the fragility level of the item, where fragility is usually expressed in terms of a dimensionless g value. For discussion of transportation shock and vibration, refer to *Shock and Vibration Handbook* (Ref. 4) and *Listing of Requirements for Missle Container Design* (Ref. 5).

Whenever the anticipated shock environment during shipping and handling is greater than an item's fragility level, some form of shock mitigation system must be incorporated into the package design. Before a shock or vibration mitigation system can be designed, certain data must be available to the packaging engineer. These data constitute the basic design criteria and include (Ref. 7):

a. Item description with dimensions, outline sketch, and center of gravity location

b. Item weight and moment of inertia about the three principal axes

c. Item shipping position, attachment points, clamping position, and permissible pressure on surface

d. Item fragility level (the number of g's the item can withstand and direction of application)

e. Maximum allowable vibration input to item–frequency and amplitude

f. Anticipated shock and vibration environment (See Table 3-2 and Chapter 15.)

g. Anticipated environmental requirements other than shock and vibration (See Chapter 16.)

h. Any special requirements, such as nuclear radiation, special testing, or inspection.

Certain items can be protected from shock by the use of shock mounts. Other items require cushioning and suspension systems. (See Figs. 3-5 and 3-6.) All containers that provide shock mitigation should be designed so that the system occupies as little space as possible. Bulk cushioning should be no thicker than necessary to provide adequate protection to the item. Similarly, when shock mounts, spring suspensions, or other flexible shock mitigation systems are used, the mechanism should be kept as small as possible, and the free space allowed for movement of the item in the container should be limited to that required for adequate protection. Sometimes the method used for attaching shock mounts and other systems to the container structure has an important effect on the cube of the container and should be considered in determining the feasibility of a design.

3-4.3.2.2 Vibration

For some items, resistance to damage caused by vibration is an important packaging consideration. In these cases, some form of vibration isolation system must be incorporated into the container design. When such systems are used, their size and the space they occupy should be kept to a minimum, the same as for shock mitigation systems.

Because shock and vibration are related phenomena (par. 15-1), it is often necessary to protect an item from both. Care should be taken in such instances so that features incorporated to protect an item from one do not aggravate the effects of the other.

3-4.3.2.3 Surface Finish

This refers to both the type of worked finish that has been accomplished on the item and to whether the surface moves on or against another item or whether another surface moves upon it. MIL-STD-647 (Ref. 3) divides this item characteristic into three basic areas: bearing surfaces, nonbearing surfaces, and "as manufactured" surfaces.

If intimate contact with the surface of another component or an assembly is involved and close fit is required, the degree of protection required will be greater than for a surface that is not critical in the functioning of the item. Other item surfaces may not move in relation to the contacting part but will have accurately controlled surfaces for intimate contact with a mating part or for close sealing. Certain surfaces such as those on reflective or optical devices will be polished or ground and, therefore, are very abrasion-susceptible.

TABLE 3-2
DYNAMIC AND SHOCK LOADINGS EXPERIENCED IN TRANSPORT

Method of Transportation	Maximum Recorded g's
Air Transport	
Shock	3
Vibration . .	8
Road Transport	
Shock	6
Vibration . .	8
Rail Transport	
Shock	20
Vibration . .	0.75
Ship Transport	
Vibration . .	1

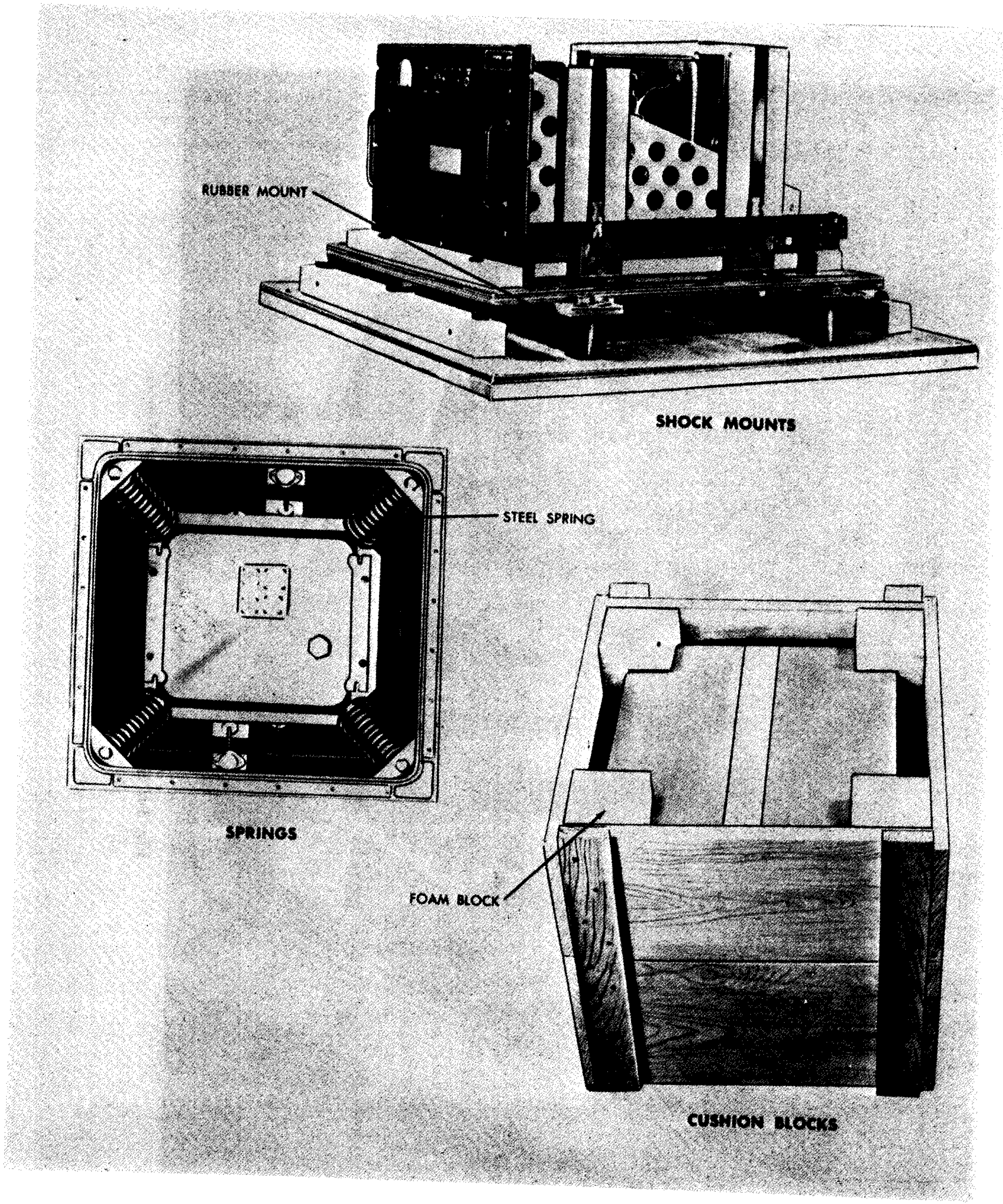

Fig. 3-5. Methods of Shock Mitigation[6]

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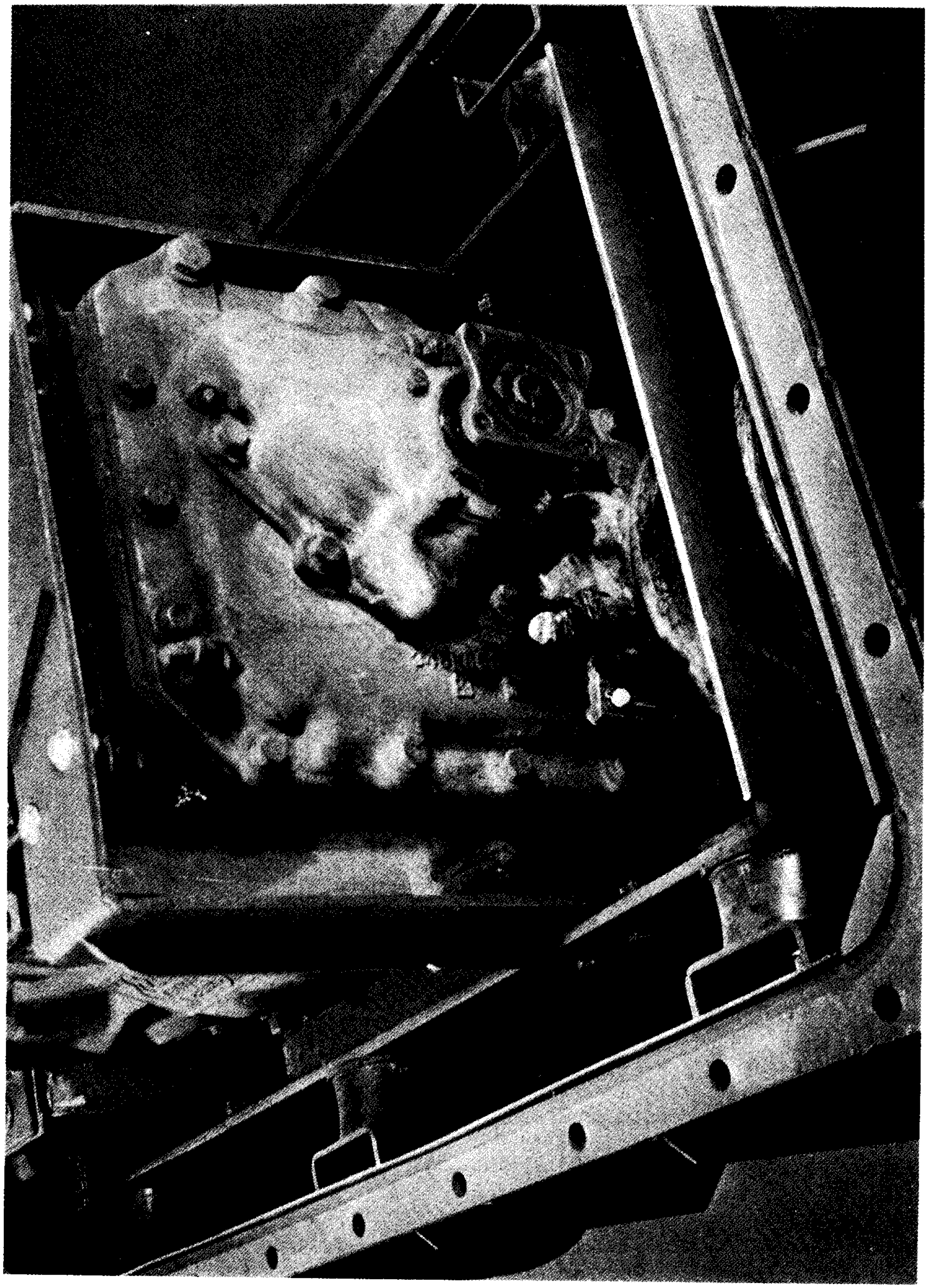


Fig. 3-6. Shock Mitigation Using Rubber Shear Mounts

Figs. 3-7 and 3-8 illustrate two items with different surface finish characteristics.

3-4.3.2.4 Degree of Hazard

Some problems of protection center on the harm that the item itself can do. Included in this group are items that use the following materials:

a. Corrosive materials

b. Flammable materials

c. Explosive materials

d. Toxic materials

e. Radioactive materials.

The following referenced documents apply to the packaging, packing, and marking of containers with dangerous and hazardous materials.

a. Tariff No. 23 (Ref. 8) covers Department of Transportation (DOT) regulations for the preparation of explosives and other dangerous articles for transportation by common carriers, rail freight, rail express, rail baggage, highway or water; construction of containers, packing, weight restrictions, marking and labeling when required; and billing and shippers' certificates for compliance with existing regulations.

b. CG 108 (Ref. 9) governs transportation of military explosives as cargo on board all domestic and foreign vessels on the navigable waters of the United States, its territories, and possessions (except the Panama Canal Zone). Included are requirements for loading, unloading, storage, handling, packing, marking, and preparation of holds and compartments for such items.

c. TM 38-250 (Ref. 10) gives instructions for preparation, packaging, packing, marking, labeling, handling, and stowing of explosives and other dangerous materials for shipment by military aircraft.

d. Bureau of Explosives Pamphlet No. 6 (Ref. 11) illustrates methods for loading and bracing carload and less than carload shipments of explosives and other dangerous articles to conform with Department of Transportation (DOT) regulations.

See Chapter 18 for more detailed data on transportation limitations for hazardous materials.

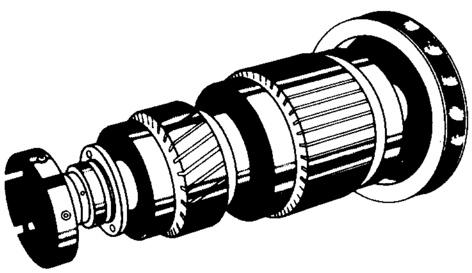


Fig. 3-7. Surface Finish Characteristics

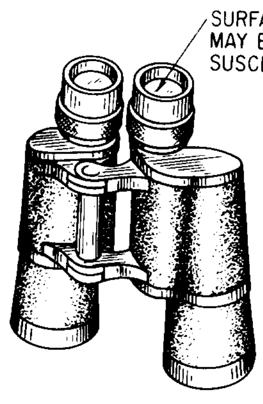


Fig. 3-8. Surface Finish Characteristics

3-4.3.3 Strength and Fragility

The degree of fragility and the rigidity of an item determine to a great extent the amount and type of physical protection that must be designed into a package.

3-4.3.3.1 Fragile, Delicate, and Rugged Items

a. *Fragile Items.* Fragility refers to the physical characteristics that permit fracturing or shattering of the item when it is subjected to moderately light impact forces. Examples of fragile items are those of glass, some plastics, and low-tensile brittle metals that are rendered vulnerable to light impact forces because they are both brittle and relatively thin. (See Fig. 3-9.)

b. *Delicate Items.* Delicate items are those so constructed that light moderate forces will either distort, displace, or deform elements in parts of the item to such an extent that malfunction or misfit of the item occurs. Delicate items generally require some provisions within the package for impact and vibration isolation. Examples of delicate items are gyroscope equipment, galvanometers, and devices with filaments. (See Fig. 3-10.)

c. *Rugged Items.* Items are generally considered to be rugged or highly resistant to shock and vibration when bracing and blocking within the container are all that is required for protection. Some items are strong and rugged except for one or more fragile component parts. (See Fig. 3-11.) When the fragile part cannot be removed for separate packaging, the entire item must

be treated as being as fragile as the most fragile component. Some items that do not require physical protection must still be packaged for ease in handling and storage.

3-4.3.3.2 Flexible and Rigid Items

Flexibility refers to both the coilability of the item and the need for stiffeners within the package. Flexible items can be formed into coils, folded, or rolled to

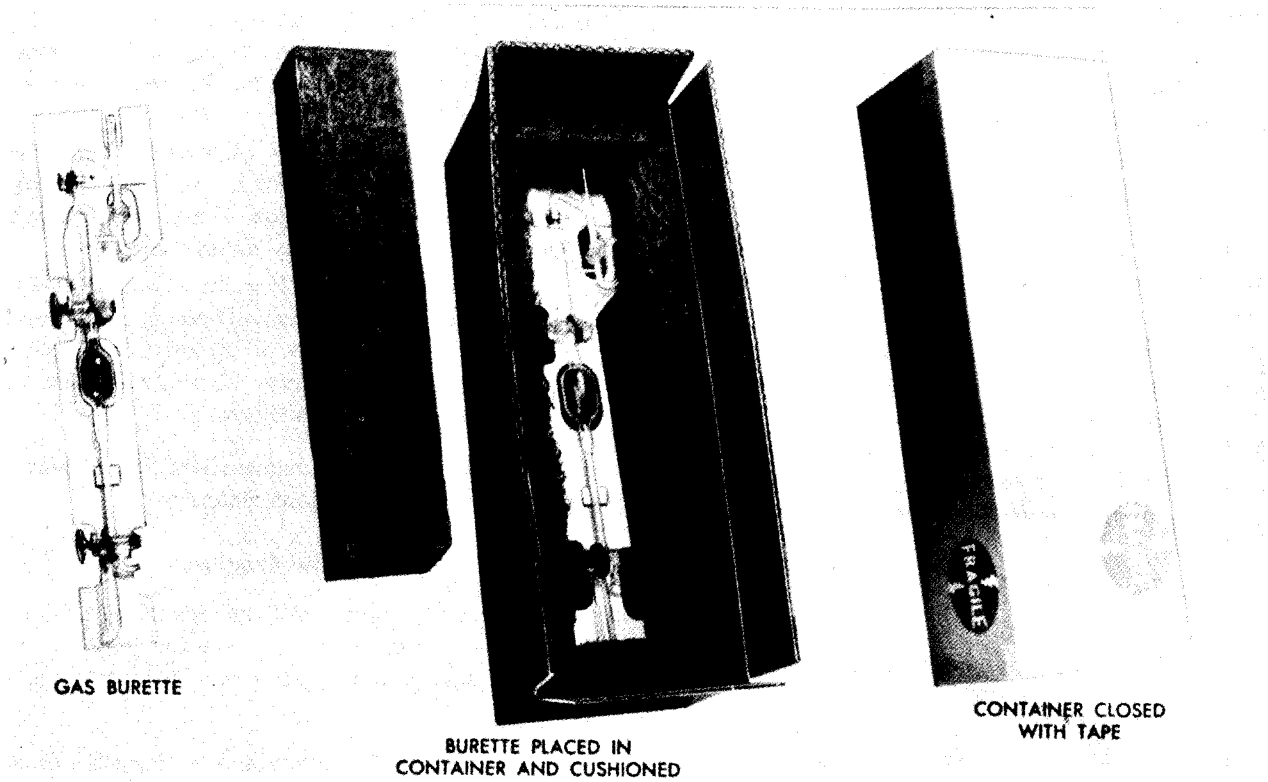


Fig. 3-9. Cushioning of a Gas Burette–a Fragile Item

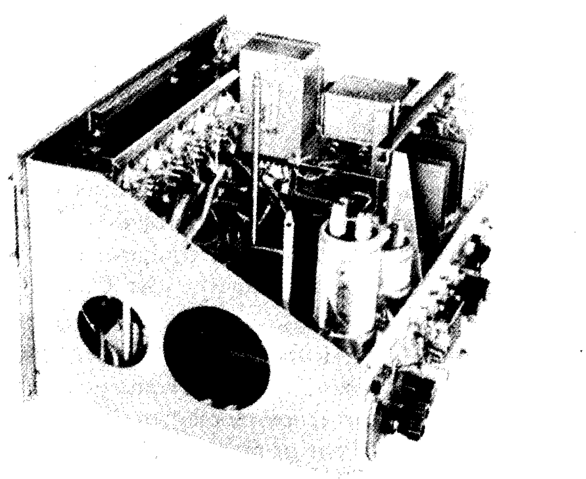


Fig. 3-10. Microwave Equipment–a Delicate Item

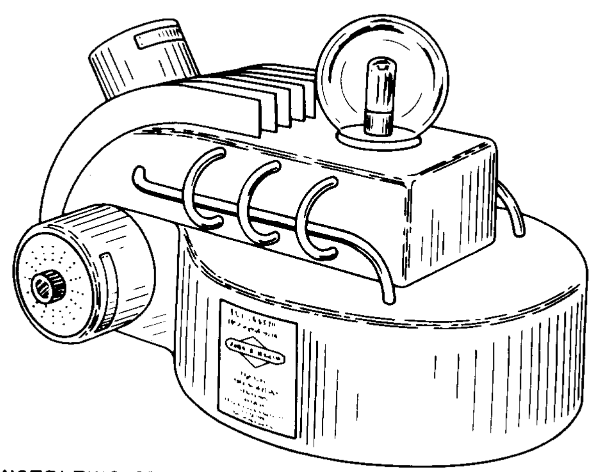


Fig. 3-11. Power Unit–a Fragile Item

provide more convenient package forms. Because of their assembly characteristics, material content, or disproportionate dimensional relationships; flexible items will change shape under very moderate pressure, including pressure exerted by the item itself when not fully supported over its load-bearing surface. Examples of flexible items are chains, cables, gaskets, and rubber items. (See Fig. 3-12.)

Rigid items are built so that force must be exerted to change their shape, but once they encounter such forces they are permanently marked, deformed, or damaged.

3-4.3.4 Type of Load

Items may be classified by the type of load they produce when packaged; i.e., their influence on the strength of, and their tendency to apply damaging forces to, the package.

An easy load would be one composed of items of moderate density packed in an inside container. For this type of load the outer container facilitates handling, and preserves and protects the surfaces of the packaged item from abrasion and weathering. Solid material, a chest, or a kit of tools are examples of easy loads.

An average load would consist of items, such as metal cans or bottles individually cushioned in cartons, that require a medium amount of protection.

A difficult load would be composed of items such as rivets, nails, or bolts that are free to shift or flow, or delicate instruments that do not completely fill the container. Such items furnish no support to the faces of the container and, in many cases, tend to concentrate forces on the container surfaces.

The center of gravity (CG) of a container may not be at the geometric center and may cause handling problems. The CG is obtained by the equal distribution of weight on both sides of the point of balance of a container. This point (CG) must be marked on the container, as specified in applicable directives, so as to aid in safe handling.

Fig. 10-2 illustrates some of the different packaging methods used to deal with these differing types of loads.

3-4.3.5 Configuration

Configuration, which is the exterior shape of an item, is a factor in determining the type and amount of cushioning and support required to retain the item within the package and to protect the package material against the forces imposed by the item on these materials. To an important degree, the amount and type of cushioning to be used is affected by the shape and severity of surface characteristics. For example, a light smooth item with no projections or protuberances requires less cushioning than a heavy item, such as shown in Fig. 3-13, having sharp edges or points that could damage the package. Cushioning required to protect the item against vibration and impact shock is determined by additional consideration of the fragility of the item and its size and weight.

3-4.3.6 Size and Weight

These characteristics are important in selecting submethods as defined in MIL-P-116 (Ref. 12), and the type and amount of cushioning required. They seldom influence the type or degree of preservation required for an item, but do directly influence the kind of container that will be used and the type, grade, and class of container applicable. For example, they provide a means of separating items that will permit a bag-type container from those requiring containers of greater strength or other desired qualities.

3-4.3.6.1 Size

A large item does not necessarily require more extensive or stronger blocking, or larger amounts of cushioning than a smaller item because of its size alone. But the container needed by the larger item may require more extensive and stronger blocking to bridge the wider spans between the container faces or frame members. Also, a large item may require that the cushioning be distributed over larger areas than on a smaller one.

3-4.3.6.2 Weight

The weight of an item determines the design of blocking, bracing, and cushioning because the impact force developed by the sudden stop of a moving item is directly proportional to its weight (mass). The heavier and more concentrated the weight of an item, the stronger must be the blocking and bracing to safeguard the life of the pack. When weights are concentrated in small areas, it may be necessary to distribute the weight over a larger area, or to transmit part of the weight from one container face to the edges or to the corners of the container.

3-4.3.7 Nature of the Item

Not all items are simple enough to be preserved and packaged by the single one-step procedures of clean, preserve, wrap, and containerize. Items may be of composite chemical nature (Fig. 3-14), contain assembly features, or be peculiarly susceptible to corrosion. They may have a chemical nature that requires preservatives on one or more areas, but will not tolerate a preservative on another area. They may also tolerate preserva-

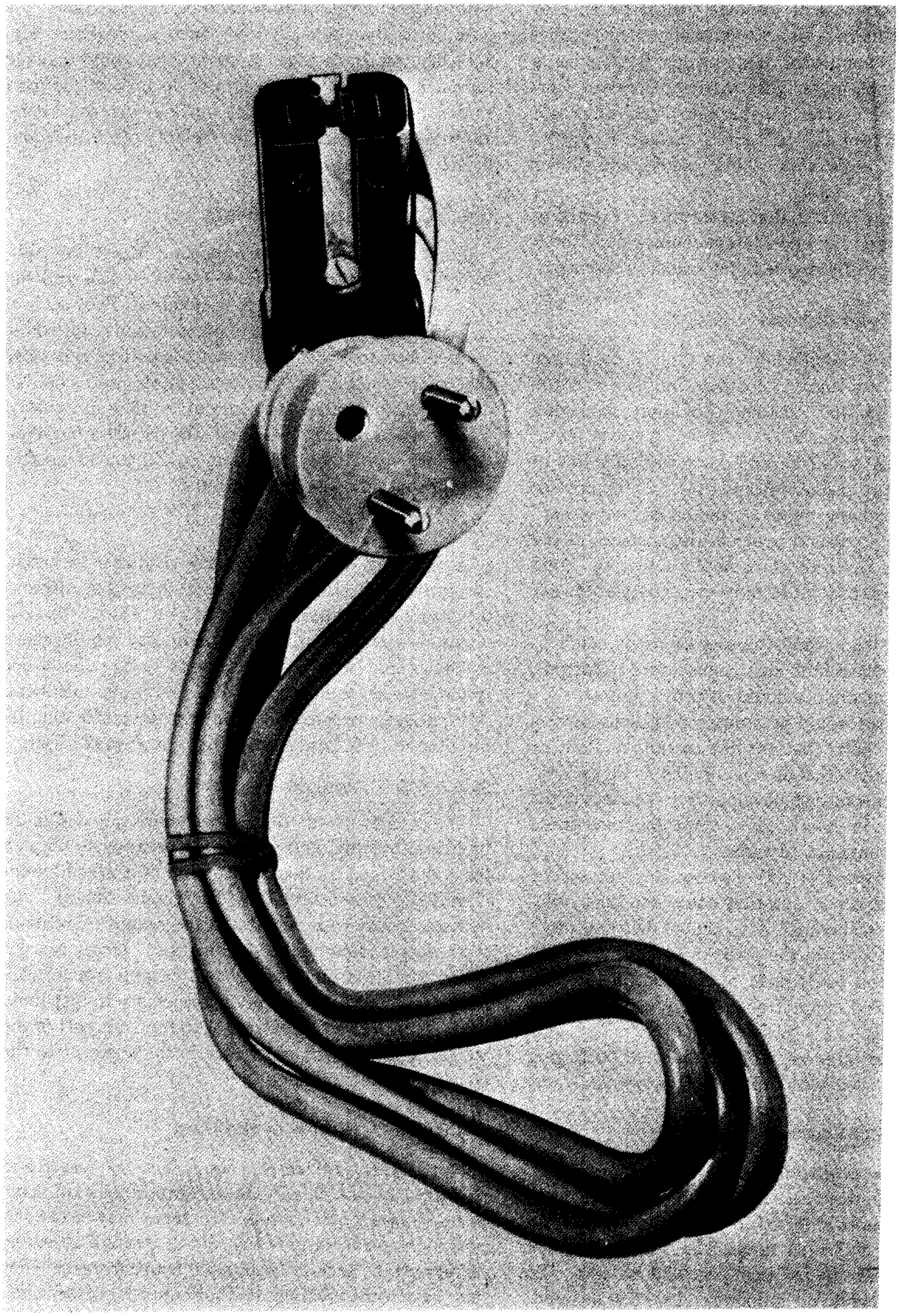


Fig. 3-12. Cable–a Flexible Item

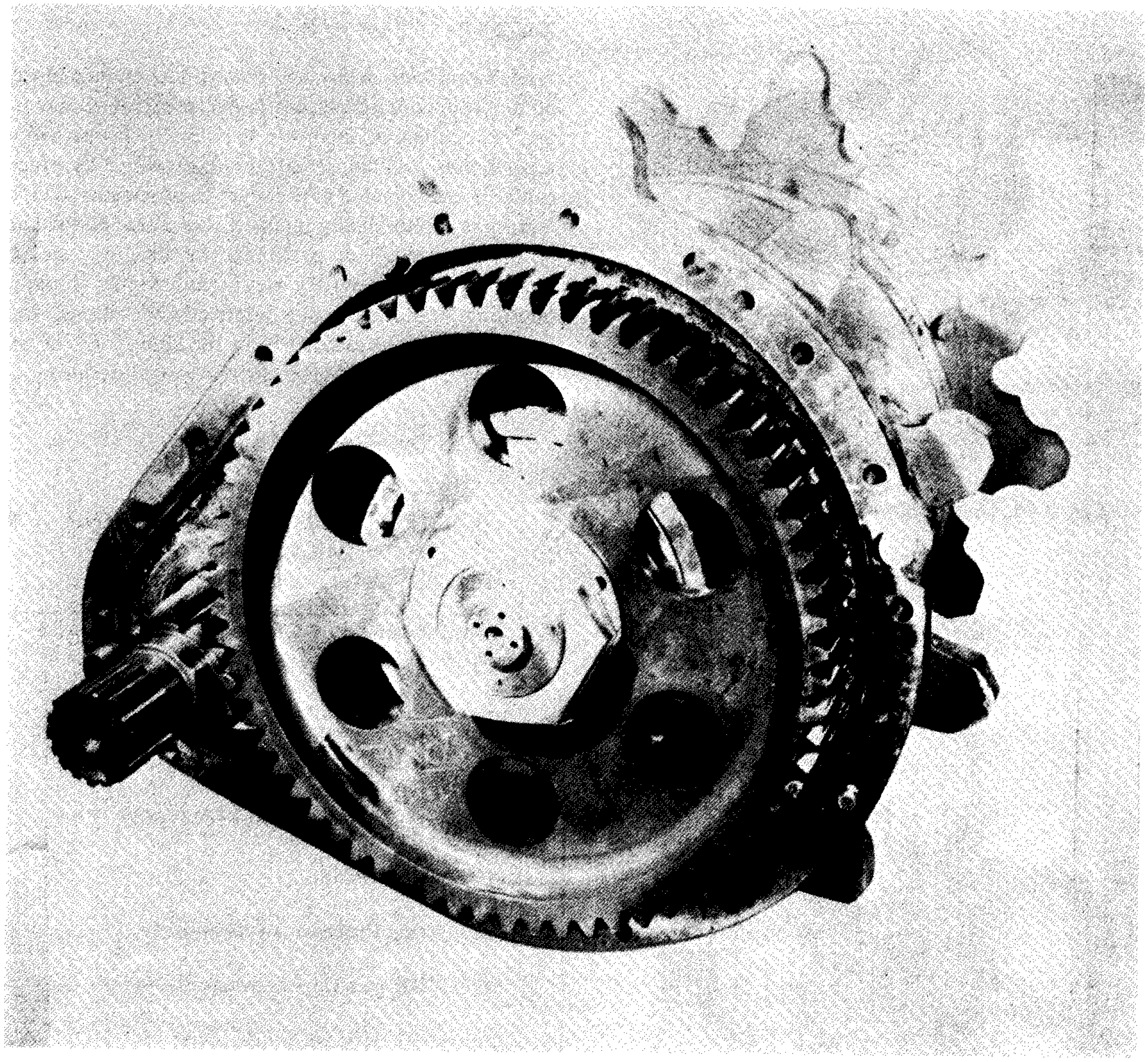


Fig. 3-13. Transmission System–a Heavy Item Having Projections

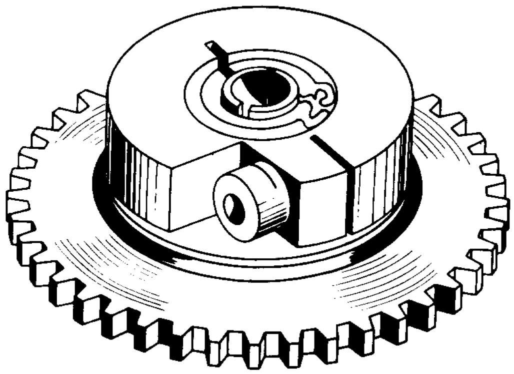
tives on all areas but not the same type of preservative on each. Or, items may be assembled in such a way that certain areas cannot or should not be in contact with a preservative. Sometimes contact type preservatives may be ruled out and another means of protection must be designated. (See Chapters 6 and 7 for a discussion of preservatives and preservation methods.)

3-4.3.8 Relation of Item Design to Package

The advantages of disassembling items to reduce the size of the package, or to simplify preservation, have been briefly mentioned in Chapter 2. However, before designing a package for a disassembled item, the packaging engineer must consider the skills, equipment, and tools needed at the point of use, and determine if these will be generally available. Also, any functional checks that must be made during storage for compatibility and recalibration must be considered when designing the package. Fig. 3-15 illustrates an item that could be disassembled, if necessary, but the reassembly time and effort might outweigh any advantages that would be gained.

3-4.3.9 Compatibility of Materials

Table 3-3 lists a number of areas where compatibility becomes a packaging consideration. If moisture is ex-



NOTE: ON THIS ITEM, THE GEAR IS LUBRICATED SINTERED BRONZE, THE BODY AND SPRING ARE CORROSION-RESISTANT STEEL, AND THE CLAMP IS ANODIZED ALUMINUM.

Fig. 3-14. Gear Unit–a Multimetallic Item

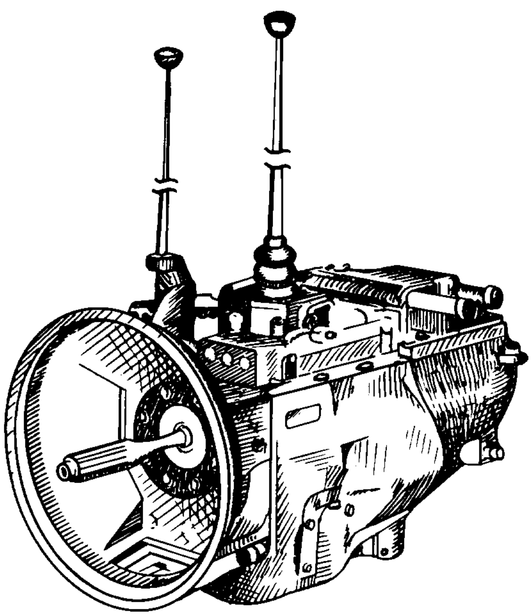


Fig. 3-15. A Packaging Engineer Consideration–Advantages and Disadvantages of Disassembly

pected as part of the environment of the item, compatibility tables similar to MIL-STD-171 (Ref. 13) should be used in the selection of packaging materials to avoid electrolytic corrosion. If incompatible metals must be used, some design features which will insulate the metals from each other should be included.

3-4.3.10 Cost of Item

Maximum efficiency and lowest cost cannot always be determined with certainty, and sometimes may appear to conflict. If the costs associated with providing a particular packaging feature are exceeded by practicable costs associated with failure to provide it, then the feature is economically justified. Costs associated with failure to provide a particular feature may not be readily apparent, but they may include higher shipping, handling, or storage costs. Safety considerations, however, cannot be evaluated from the standpoint of cost alone. They must be given primary consideration.

TABLE 3-3
COMPATIBILITY OF PACKAGING MATERIALS

A. Compatibility of Cleaning Methods and Materials:

 (1) With items.

 (2) With packaging materials.

B. Compatibility of Preservatives:

 (1) With items.

 (2) With unclean surfaces.

 (3) With packaging materials.

C. Compatibility of Inhibitors:

 (1) With nonferrous metals.

 (2) With nonmetals.

 (3) With preservatives.

 (4) With packaging materials.

D. Compatibility of Metal Platings.

E. Compatibility of Dissimilar Materials.

F. Other Compatibility Data:

 (1) Naphthalene on asphalt laminates.

 (2) Rocket fuels on packaging materials.

REFERENCES

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10. TM 38-250, *Packaging and Materials Handling of Dangerous Materials for Transportation by Military Aircraft.*
11. Bureau of Explosives, *Explosive Pamphlets Nos. 6 and 6A,* Association of American Railroads, Chicago, Illinois.
12. MIL-P-116, *Preservation, Methods of.*
13. MIL-STD-171, *Finishing of Metal and Wood Surfaces.*

CHAPTER 4

DETERIORATION

Item characteristics that make some military items vulnerable to deterioration are briefly discussed in the preceding chapter. Chapter 4 describes in detail the types of deterioration caused by the contributing factors of climate, physical forces, chemical agents, and biological agents. Chapters 5, 6, and 7 discuss methods and materials prescribed by the packaging engineer to help combat this deterioration.

4-1 DETERIORATION OF METAL

Except for the physical changes brought about by low temperatures, deterioration of metals is in the form of corrosion. Corrosion of metals (Fig. 4-1) is closely related to the environment, particularly the temperature, humidity, and the presence of chemicals. The destructive effects of moisture, chemical action, electrochemical action, and low temperature and their prevention are described in pars. 4-1.1 to 4-1.5.

4-1.1 MOISTURE

Most metals corrode in the presence of moisture. The rate of corrosion is influenced by the manner in which the moisture is applied. Alternate wetting and drying, as created by a spray, causes rapid corrosion whereas immersion, as caused by condensation of a thin water layer, is even more destructive. A high relative humidity level is particularly harmful resulting, for example, in an 80 percent increase in the corrosion rate of steel and a significant increase in the corrosion rate of zinc. Besides causing corrosion through simple chemical oxidation, moisture also causes corrosion by electrochemical action.

4-1.2 CHEMICAL ACTION

Corrosion of metals by reaction with chemical substances in the environment occurs under a variety of circumstances. Most chemical attacks depend on moisture to be effective. Airborne contaminants are an important part of the corrosion process, especially in areas subject to fog, because the water vapor acts as a vehicle to place the contaminant in contact with the package.

The packaging engineer does not usually become concerned with protecting exclusively against corrosion resulting from direct chemical attack of active gases on metals. If corrosion caused by electrochemical action is eliminated or prevented through packaging, then direct chemical attack is also prevented.

Salt water is particularly corrosive. Free acids and alkalies are encountered in airborne contaminants and in large concentrations in soil and natural waters. These three corrosive agents are described in the paragraphs which follow.

4-1.2.1 Salts

Salts in soil and water are the most widely distributed and troublesome of the corrosive chemical agents. The natural salts causing the greatest trouble are the chlorides (particularly sodium chloride because it is the most frequently encountered), nitrates, sulfates, phosphates, and occasionally carbonates. Salts of weak acids and strong bases or strong acids and weak bases hydrolyze, forming acids and bases, which results in the corrosion of metals by direct chemical action. Also, all salts do ionize in solution, causing corrosion by electrochemical action.

The specific effect of a salt upon a metal depends on the chemical and electrochemical relationship between them. Iron and steels are affected primarily by sodium chloride salt spray. Aluminum is relatively immune to sodium chloride salt spray, but is readily attacked by the salts of strong bases and weak acids–such as the sodium, potassium, and ammonium salts of acetic, oxalic, and tartaric acids. The effects of salt solutions on various metals are given in Tables 4-1 and 4-2.

4-1.2.2 Acids and Alkalies

Because of their high activity, free acids and bases are rarely encountered in natural environments. An important exception, however, is the high acid concentration in airborne contaminants. Industrial atmospheres are the worst offenders in this category. The

high concentration of sulfur dioxide and carbon dioxide in industrial atmospheres form sulfurous acid and carbonic acid in the presence of water vapor.

Carbonic acid is a fairly weak acid, resulting in minimal deterioration. Sulfurous acid, however, is a very strong acid and may even be oxidized under suitable circumstances to form the more powerful sulfuric acid. The latter two acids are extremely corrosive. In dilute solutions and hot concentrated solutions, these two acids attack iron, steel, copper and zinc compounds, and aluminum to some extent. Hydrogen sulfide is another sulfur compound frequently found in industrial atmospheres, though its corrosive effects are limited primarily to steel. The effects of the most prevalent industrial contaminants on metals are shown in Table 4-3.

4-1.3 ELECTROCHEMICAL ACTION

Attack by electrochemical (or galvanic) action accounts for more destruction of metals than any other form of corrosion. The deterioration process occurs in the manner described.

Wherever two dissimilar metals are in contact and exposed to water or another electrolyte, a galvanic cell will be formed and current will flow. The rate of current flow depends on the potential difference, which in turn is dependent on the relative dissimilarity of the metals. Galvanic action usually results in the progressive corrosion of the more positive of the two metals with the action continuing as long as an electrolyte is present. There are usually sufficient differences between adjacent crystals of a metal for this action to take place. Where different metals such as aluminum and steel are coupled, the potential difference is greater and therefore the attack is accelerated.

The electrochemical series listed in Table 4-4 reveals the relative electromotive potential of various metals. Usually, the greater the separation of two metals, the greater is the corrosion problem. However, corrosion is also a function of the concentration of the cations of the metal in solution and the presence of complexing agents.

Corrosion may be either the surface type or intergranular; the latter being the more dangerous. Theoretically, as long as the relative humidity is kept below the saturation point, corrosion should not occur. But in practice, surface absorption and condensation of water vapor by particles of hygroscopic matter may

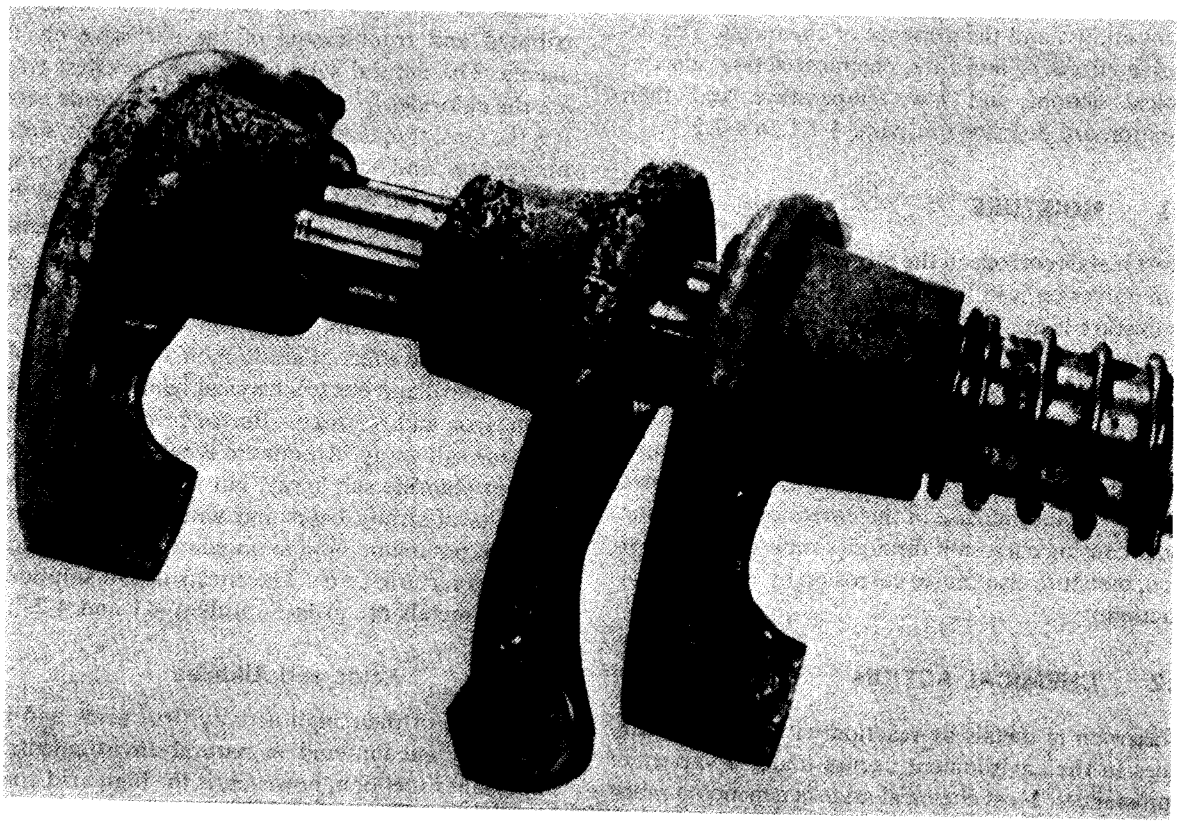

Fig. 4-1. Rusted Rocker Arm of Truck Engine–After Storage

TABLE 4-1
CORROSION RATES OF STEEL AND CAST IRON IN VARIOUS SALT SOLUTIONS[2]

Salt Solution	Temperature		Duration of Test, days	Corrosion Rate			
				Steel		Cast Iron	
	°C	°F		mdd*	ipy**	mdd*	ipy**
5% Calcium chloride	16	60	--	35	0.006	48	0.009
30% Calcium chloride	-12	10	355	--	--	34	0.006
30% Calcium chloride (with $K_2Cr_2O_7$ inhibitor)	-12	10	372	--	--	2	0.0004
46% Calcium chloride	180	360	11	28	0.005	--	--
6.6% Ammonium thiocyanate	room	room	13-1/2	30	0.006	15.0	0.003
30% Ammonium thiocyanate	68	154	17	442	0.08	520	0.10
5% Ammonium sulfate	16	60	--	49	0.009	138	0.03
10% Ammonium sulfate	16	60	--	50	0.009	151	0.03
25% Ammonium sulfate	16	60	--	17	0.003	57	0.012

(Contributed by H.O. Teeple, International Nickel Co., Inc., New York, N.Y.)

* Milligrams per square decimeter per day.

** Inches per year.

TABLE 4-2
CORROSION OF MAGNESIUM ALLOYS IN SALT SOLUTIONS

Alloy - Mg: 6% Al, 1% Zn, 0.2% Mn
Specimen size: 7.5 x 2.5 x 0.15 cm (3 x 1 x 0.06 in.)
Surface preparation: HNO_3 pickled
Temperature: 35°C (95°F)
Volume of testing solution: 100 ml
Duration of test: 7 days
Test - alternate immersion: 30 sec in solution, 2 min in air
Concentration of solution: 3% by weight

Acid Salts	Corrosion Rate, mdd*	Neutral Salts	Corrosion Rate, mdd*	Alkaline Salts	Corrosion Rate, mdd*
		Nonoxidizing			
Aluminum sulfate	112	Sodium chloride	14	Sodium silicate meta	0.7
Zinc chloride	770	Sodium bromide	6	Sodium sulfite	2
Sodium acid tartrate	155	Sodium iodide	29	Sodium borate, meta	5
Sodium dihydrogen phosphate	85	Sodium fluoride	3	Sodium phosphate	3
		Sodium sulfate	8		
		Sodium nitrate	5		
		Oxidizing			
Ammonium persulfate	465	Sodium chromate	2	Calcium hypochlorite	155
Sodium dichromate	4	Sodium chlorate	59	Sodium hypochlorite	5
Ferric sulfate	297	Sodium pyrophosphate	51	Sodium iodate	40

* Milligrams per square decimeter per day

TABLE 4-3
RESISTANCE OF METALS TO WATER SOLUTIONS OF AIRBORNE GASES[2]

Metal	Carbon Dioxide[1] and Water		Sulfur Dioxide[2], Air, and Water		Hydrogen Sulfide[3] and Water	
	Avg Wt Loss, gram	Avg ipy[4][6]	Avg Wt Loss, gram	Avg ipy[4]	Avg Wt Loss, gram	Avg ipy[4]
Aluminum(2S)	0.0003	0.00004	0.150	0.0498	0.002	0.00028
Copper	--	--	0.681	0.0701	0.237	0.01030
Steel	0.2153	0.00977	8.583[5]	1.02[5]	1.366	0.06800

Notes:

(1) Metal specimens 1 x 4 x 1/16 in. (2.5 x 10.2 x 0.16 cm) were partially immersed (to a depth of 2 in.) (5.1 cm) in distilled water through which carbon dioxide and air were bubbled. The total period of exposure was 342 hr at room temperature.

(2) Metal specimens 1 x 4 x 1/16 in. thick were partially immersed (to a depth of 2 in.) in distilled water through which air and sulfur dioxide were bubbled. The total period of exposure was 135 hr at room temperature.

(3) Metal specimens 1 x 4 x 1/16 in. were partially immersed (to a depth of 2 in.) in distilled water through which hydrogen sulfide was bubbled. The total period of exposure was 320 hr at room temperature.

(4) This calculation was based on the assumption that all corrosion was confined to the immersed areas of the specimens.

(5) Steel specimen corroded completely through at the water line.

(6) ipy - Inches per year.

TABLE 4-4
ELECTROCHEMICAL SERIES

Anodic (Positive) End	
Lithium	
Rubidium	
Potassium	
Calcium	
Sodium	
Strontium	
Barium	
Magnesium	
Beryllium	
Aluminum	
Manganese	
Zinc	
Chromium	
Gadolinium	
Iron (Fe^{++})	
Cadmium	
Indium	
Tellurium	
Cobalt	
Nickel	
Tin	
Lead	
Iron (Fe^{+++})	
Hydrogen	(neutral)
Antimony	
Bismuth	
Arsenic	
Copper	
Iodine	
Silver	
Palladium	
Mercury	
Platinum	
Gold	
Cathodic (Negative) End	

produce liquid films or spots even though the air may be comparatively dry.

To minimize the incidence of electrochemical attack, metallic components of items should be designed without recesses, cups, or traps where liquids can accumulate. Metals in contact should be chosen as close together as possible in the electromotive force series. Exposed surfaces should be completely covered by some form of protective coating or surface plating. Corrosion inhibitors or preservative materials should be used whenever necessary or possible.

Although moisture is the electrolyte in most galvanic action, salt solutions support even more vigorous deterioration. Extreme care must be exercised in the protection of metal items that may be transported via ship or stored in proximity to salt water. Slight alteration occurs in the electrochemical series when salts are present in the electrolyte. Table 4-5 lists the galvanic series for a variety of metals and alloys in sea water. Table 4-6 gives the corrosive effects of this action on magnesium and other dissimilar metals in salt solution. The effects of distilled water on the same metal combinations are included for comparison.

4-1.4 LOW TEMPERATURES

As the temperature decreases, most metals undergo transient changes in properties that make them susceptible to failure in areas of high stress concentration. The metals become stronger and stiffer but also more brittle at very low temperatures. Some of these transition temperatures are surprisingly high; for example, approximately 32°F for some steels that are not thoroughly deoxidized.

Although the packaging engineer can do nothing to prevent the occurrence of this transition, he should be aware of these properties of metals. In consultation with the item designer, he may perhaps recommend that certain metals or certain manufacturing processes not be used for cold-temperature use.

4-1.5 CORROSION PREVENTION

For the packaging engineer, the problem is to eliminate hygroscopic matter and to maintain a relative humidity in which surface condensate will not form. Metal items must be thoroughly cleaned and dried before packaging, residual moisture must be removed as rapidly as possible after packaging, and a low relative humidity must be maintained for the life of preservation. Desiccants are frequently used for this purpose. But if hygroscopic matter and residual moisture are not removed before a package containing desiccant is sealed, they may start corrosion before they can be dried by the desiccant. Preservation may also be achieved by sealing dry inert gases within the package or by using controlled humidity warehouses.

The destruction of metals can be reduced in the manufacturing stage through the use of corrosion-resistant coatings of metal, paint, and plastic, and by surface treatment of the metal with semipermanent corrosion preventive materials. These methods result in a significant increase in the service life of the metal. The

TABLE 4-5
GALVANIC SERIES IN SEA WATER[1]

1.	Magnesium	19.	Muntz metal
2.	Magnesium alloys	20.	Manganese bronze
3.	Zinc	21.	Naval brass
4.	Galvanized steel	22.	Nickel (active)
5.	Aluminum (52SH, 61S, 3S, 2S, 53ST in this order)	23.	Inconel (active)
6.	Aluminum clad, 24ST, 17ST	24.	Yellow brass
7.	Cadmium	25.	Admiralty brass
8.	Aluminum (75ST, A17ST, 17ST, 24ST in this order)	26.	Aluminum bronze
9.	Mild steel	27.	Red brass
10.	Wrought iron	28.	Copper
11.	Cast iron	29.	Silicon bronze
12.	Ni-Resist	30.	Ambrac
13.	13% chromium stainless steel, type 410 (active)	31.	70-30 copper nickel
14.	50-50 lead-tin solder	32.	Comp. G-bronze
15.	18-8 stainless steel, type 304 (active)	33.	Comp. M-bronze
16.	18-8-3 stainless steel, type 316 (active)	34.	Nickel (passive)
17.	Lead	35.	Inconel (passive)
18.	Tin	36.	Monel
		37.	18-8 stainless steel, type 396 (passive)
		38.	18-8-3 stainless steel, type 316 (passive)

use of these methods is described in the paragraphs which follow.

4-1.5.1 Metal Coatings

Steel is most often protected by a corrosion-resistant metal coating. Cadmium, zinc, nickel, chromium, tin, and lead are the metals most frequently used for this purpose. All of these metals can be electroplated on to steel, although zinc, tin, and lead can also be applied by hot-dip. Cadmium and zinc protect steel and greatly reduce corrosion caused by the contact of steel with aluminum or magnesium alloys.

4-1.5.2 Paint

Paint is frequently employed to prevent corrosion by protecting the surface of the metal from moisture. To be really effective against the more severe environmental conditions such as salt spray and other chemical-laden fluids, a special corrosion-inhibiting primer must be applied to the metal surface prior to painting. These primers usually consist of liquid vehicle or binder and a corrosion-inhibiting pigment. The most common inhibitive pigments are red lead (lead oxide) and zinc yellow (zinc chromate). Red lead is popular for steel, but lighter zinc pigments must be used if weight is a factor. Table 4-7 lists several paint primers.

4-1.5.3 Semipermanent Surface Treatment

Chemical treatment of sheet metal to produce a corrosion-resistant surface is often used for aluminum and steel. Treatment of the metal surface with certain chemical solutions produces a thin corrosion-resistant film. Table 4-8 lists the treatments used to protect aluminum; Table 4-9 lists the treatments used to pro-

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TABLE 4-6
CORROSION OF Mg: 6% Al: 3% Zn, 0.2% Mn ALLOY GALVANICALLY CONNECTED TO OTHER METALS IN VARIOUS MEDIA[2]

Size of specimens: 4 x 1.3 x 0.2 cm (1.5 x 0.5 x 0.079 in.)
Relative areas: 1:1 (mounted face to face)
Surface preparation: Aloxite 150 ground
Temperature: room
Aeration: natural convection
Volume of testing solution: 100 ml
Velocity: quiescent
Duration of test: 3% NaCl, 3 hr; Midland tap water, 24 hours; Distilled water, 4 days

Dissimilar Metal	Corrosion Rate, mdd *				
	3% NaCl				Distilled Water
	Close Contact	Separation 0.35 cm	Separation 2.0 cm	Separation 10 cm	Separation 0.35 cm
Steel	23,400	25,500	8300	3900	18
24ST Aluminum	12,800	25,700	6800	3200	6
Nickel	18,800	22,400	6600	--	19
2S Aluminum	14,500	15,600	4100	--	4
Copper	8500	8200	3700	--	15
Brass	7100	4000	2500	1700	14
56S Aluminum	--	1900	--	--	3
Cd-Plated Steel	5200	2200	1000	--	14
Zinc	6200	1300	900	700	8
Mg-1.5% Mn	--	50	--	--	3
Mg-6% Al,3% Zn,0.2% Mn	--	200	--	--	3

* Milligrams per square decimeter per day.

TABLE 4-7
TYPICAL PAINT PRIMERS[3]

Type	Ingredients lb /100 gal paint										Properties			
	Zinc Yellow	Red Lead	Basic Lead Sulfate	Zinc Oxide	Iron Oxide	Inert Pigments	Other Pigments	Vehicle Solids	Thinners and Dryers	Phosphoric Acid (85%)	Wt/gal, lb	Red coating Time, hr	Color	Suggested Use
Automotive	38			25	257	197		205(A)	393		11.2	18	Red	I
Automotive and equipment		1345 (95%)			448			344(A, O)	177		23	16	Brownish red	I, II
General purpose	149		447(B)	105		176		226(A)	355		14.6	12	Gray	I, II, III
Aircraft	280						50	265(A, P)	400		9.9	6	Yellow	II, III
Ship bottom	65					40		115(R)	610		8.1	18	Yellow	III, IV
Ship bottom			588(W)		591		295(C)	303(V)	383		21.5	12	Red	IV
Marine primer	71	391 (97%)		71	50	128		364(A, O, V)	269		13.5	4-8	Brownish red	III, IV
Wash primer	54					8		56(S)	630	28	7.5	1	Yellow	V

Vehicle

(A) Alkyd resin
(O) Oil, vegetable drying
(V) Varnish, oleoresinous
(P) Phenolic resin
(R) Vinyl resin
(S) Polyvinyl butyral resin

Pigment

(B) Blue lead sulfate
(W) White lead sulfate
(C) Lead carbonate

Usage

I Mild atmospheric exposure
II Severe atmospheric exposure
III Tidewater atmospheric exposure
IV Submerged—sea water
V Pretreatment coating

tect steel. The temporary surface treatments which the packaging engineer uses for different item surfaces are reviewed in Chapter 3.

4-2 DETERIORATION OF WOOD

Wood is subject to deterioration by the factors of climate, physical forces, chemical agents, and biological agents. Wood and wood products being organic in nature are highly susceptible to biological agents, especially micro-organisms and insects. The deterioration of wood is particularly severe when suitable environmental conditions such as moisture and warmth favor the biological agents.

TABLE 4-8
SURFACE TREATMENTS FOR ALUMINUM[3]

Type	Remarks
Anodic	--
Chemical conversion	Not for extremely severe exposure
Chromic acid wash	Used primarily on the more corrosion-resisting alloys and on electronics items
Alcoholic phosphoric acid wash	Same as above
Caustic etch	Electronics items only

TABLE 4-9
SURFACE TREATMENTS FOR STEEL[3]

Type	Most Common Usage
Phosphate (heavy)	Guns, some engine parts
Phosphate (paint base)	Noncritical steel parts, ground equipment
Phosphate (oiled)	Engine parts, guns, internal working surfaces where plating is impractical or undesirable
Black oxide	Parts continuously coated with oil

TABLE 4-10
HEARTWOOD DECAY RESISTANCE OF SOME WOODS COMMON IN THE UNITED STATES[3]

Good(1)	Fair(1)	Poor(1)
Baldcypress Catalpas Cedars Chestnut Junipers Locust, black Mesquite Mulberry, red Osage-orange Redwood Walnut, black Yew, Pacific	Douglas fir Honey-locust(2) Larch, western Oak, chestnut Oak, white Pine, eastern white Pine, southern yellow Sassafras	Ashes(2) Aspens Basswood Beech(2) Birches(2) Cottonwood Firs (true) Hemlocks(2) Maple, sugar(2) Oak, northern red(2) Spruces(2) Willows

Notes:
(1) The species in each group are listed alphabetically, it being impractical to list them in order of relative decay resistance.
(2) These species may rate nearly as high in decay resistance as some of those in the next better group.

4-2.1 MICRO-ORGANISMS

Wood in contact with the ground is susceptible to attack by fungi and molds, particularly in a moist and warm environment. Most of these organisms cause decay which drastically reduces the structural properties of wood, whereas others do not damage the wood, but quickly deteriorate certain plywood glues. Under humid conditions, molds and fungi can stain wood in a few days, even if the wood is supported off the ground, and can eventually cause decay.

Items being shipped to areas where optimal conditions for decay are prevalent should use decay-resistant or decay-treated woods. Table 4-10 lists the decay resistance of some woods.

Protection against micro-organisms and most insects is obtained by the use of wood preservatives which make wood unpalatable or uninhabitable to wood-destroying organisms. Some of these substances are poisonous to the attacking organisms, while some are repellents. Still others form a physical barrier that prevents the organism from entering the wood or depositing eggs in its pores in the case of certain insects. Wood preservatives may make use of oil or water. Oil-borne preservatives are not washed away or leached out by water and, as a result, they make the wood moisture-repellent. The primary advantage of water-borne preservatives is that the water vehicle for the chemical substance is low-cost. Table 4-11 lists various wood preservatives. Also refer to MIL-STD-171 (Ref. 6) for another classification.

4-2.2 INSECTS

Wood in contact with the ground is subject to attack by many insects, particularly termites and powder-post beetles. Wood supported above the ground and kept dry is also subject to attack by these insects, although to a much lesser degree. In this case, the subterranean termites have to build tubes up from the soil to reach the wood. Insect damage to crates supported above the ground is due primarily to power-post beetles and dry-wood termites.

The wood preservatives used to protect against micro-organisms are also effective in combatting insect infestation by coating the surface of the wood with an oil or paint film that will prevent the deposition of eggs in the wood pores.

4-2.3 PHYSICAL AGENTS

Abrasion, weathering, and high temperatures all cause deterioration of wood products. Abrasion usually occurs during shipment and handling. Little can be done to combat this other than choosing a hard, abrasion-resistant wood, and reinforcing at the points where excess wear occurs.

Long exposure to high temperatures causes gradual loss of strength with the rate of loss increasing with the temperature. Similar results occur when unfinished wood is exposed to the weather for an extended period of time. Alternate periods of rainfall and hot, dry weather produce cracks, splits, and general erosion of wood, eventually resulting in severe loss of structural properties. In extreme conditions where long life must be assured, wood products should be protected from the elements. Generally this is of concern in reusable containers.

TABLE 4-11
WOOD PRESERVATIVES

Oil-Borne	Water-Borne
Coal-tar Creosotes Creosote-coal Tar Solution Creosote-petroleum Solution Wood-tar Creosote Lignite-tar Oil Copper Naphthalate Pentachlorophenol Zinc Naphthalate	Cupric Chromate ("Celcure") Chemonite Chromated Zinc Chloride "Wolman" Salt Tanalith Zinc Chloride Zinc Metaarsenite "Greensalt" "Erdalith" "Boliden Salt" "Minalith" "Pyresote" CZC (FR)

4-2.4 CHEMICAL ACTION

Wood products are readily destroyed by chemicals. The effects of various chemicals on some common woods are given in Table 4-12. Where economics of the situation warrant, resistant wood should be selected for shipping containers that may be subjected to these conditions.

4-3 DETERIORATION OF PAPER PRODUCTS

Paper products are often wood derivatives, hence they are subject to many of the deteriorating agents affecting wood.

4-3.1 MOISTURE

Moisture in the form of water or water vapor can cause deterioration of paper in two principal ways. When ordinary paper becomes wet, it loses its structural strength and falls to shreds because the moisture dissolves or softens the gelatinous binder intended to hold the fibers together. However, wet-strength papers are available to overcome this problem. An indirect but important effect of moisture on paper is to make the paper habitable for the growth of micro-organisms, which result in decay.

4-3.2 MICRO-ORGANISMS

Under conditions of moisture and warmth, microbiological attack of paper, paperboard, and fiberboard deserves serious attention. Mildew, bacteria, and fungi are the chief offenders. Some micro-organisms merely deface or stain paper, but serious damage occurs when the cellulose content of paper is consumed. This can completely destroy the paper. Treatment of the paper with fungicides and mold-inhibiting solutions is the accepted preventive measure. Compounds used for treating paper are listed in Table 4-13.

4-3.3 INSECTS

Insects damage paper because they use it as food. Termites consume paper for its prime structural component, cellulose, whereas silverfish destroy paper by eating the starchy material, such as glue and sizing. Cockroaches feed on many materials, particularly book bindings. The cellulose-eating insects (termites and cockroaches) will attack sheet paper, pasteboard, composition board, fiberboard, labels, paper boxes, insulating paper, and tarpaper. The time required for these insects to penetrate various materials is given in Table 4-14.

Insecticides incorporated into the packaging material and sprayed or baited around storage areas are an effective means of controlling insect and rodent damage. Substances used for this purpose are listed in Tables 4-15 and 4-16. The insecticides and repellents

TABLE 4-12
CONDITION OF WOODS AFTER IMMERSION IN CHEMICAL SOLUTIONS

After 31 Days Immersion in Cold Solutions. (Examined after 7 days drying)*

		Fir	Oak	Yellow Pine	Oregon Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric acid,	5%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
	10%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
	50%	SS,SB,SWF	SS,WF	S,WF	S,WF	S,WF	S,WF	S,WF	S,WF
Sulfuric acid,	1%	NAC	NAC	NAC	SS	SS	NAC	NAC	SS,SB
	5%	SS	SS	SS	SS	SS,SB	SS,SB	NAC	SS,SB
	10%	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD
	25%	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD
Caustic soda,	5%	S,NAC	MSh,SWp	SS	SS,FSD	SSp,FSD	SSp,FSD	MSh	SSp,FSD
	10%	S,FSD	MSh,WF	SS	SS,SB,FSD	SS,SB,FSD	SS,SB,FSD	MSh	S,SB,FSD
Alum	13%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium carbonate,	10%	S,GC	NAC	GC	SB,GC	SB,GC	SB,GC	GC	SB,GC
Calcium chloride,	25%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Common salt,	25%	NAC	NAC	NAC	SS,GC	SS,GC	SB,GC	NAC	NAC
Water		NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium sulfide,		SS,SB	MSh,WF	SB	SB	SB	SB	MSh,FSD	FSD

After 8 Hours in Boiling Solutions (Examined after 7 days drying)*

		Fir	Oak	Yellow Pine	Oregon Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric acid,	10%	SB,S	FSD	FSD	FSD	FSD	FSD	FSD	FSD
	50%	FD,Ch,B,S,NG	FS,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG
Sulfuric acid,	4%	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC
	5%	SS,GC	SB,GC	SB,GC	SB,GC	SB,FSD	SB,GC	SB,GC	SB,FSD
	10%	SS,GC	B,FD,Wpd,NG	Sp,FD,NG	B,Sp,FD,NG	B,Sp,FD,NG	SB,FSD	SB,FSD	B,FD
Caustic soda,	5%	SS	MSh	S	GC	S,GC	S,GC	Sh	SSp
Alum,	13%	SB,GC	NAC	NAC	SB,GC	SB,GC	SB,GC	NAC	SB,GC
Sodium carbonate,	10%	SB,GC	GC	GC	GC	GC	GC	GC	SB,GC
Calcium chloride,	25%	SB,GC	SB,SS,GC	NAC	SB,GC	SB,GC	NAC	NAC	SB,GC
Common salt,	25%	NAC	NAC	NAC	SB,GC	NAC	SB,GC	NAC	NAC
Water		NAC	NAC	NAC	SB,GC	NAC	NAC	NAC	NAC

*Note:

The condition of eight varieties of woods used for tanks and other chemical-resistant uses are based on a report of James K. Stewart, consulting chemist to the Mountain Copper Co., Martinez, Calif. Tests were conducted on samples 1 x 4 x 1/4 in. in size, seasoned and chosen so as to be nearly as possible in the same physical condition as the woods would be when used for equipment construction. Results of the tests are described by terms explained in the following key:

Abbreviation Key

- B - Brittle
- Ch - Charred
- FD - Fiber Disintegrated
- FSD - Fiber Slightly Disintegrated
- GC - Good Condition
- MSh - Much Shrunk
- NAC - No Apparent Change
- NG - No Good
- S - Softer
- SB - Slightly Brittle
- Sh - Shrunk
- Sp - Spongy
- SS - Slightly Softer
- SSp - Slightly Spongy
- SWF - Slightly Weakened Fiber
- SWp - Slightly Warped
- WF - Weakened Fiber
- Wpd - Warped

TABLE 4-13
TREATMENT FOR MICRO-ORGANISMS[3]

Treating Method or Compound Used	Treating Method or Compound Used
Acetone	Mercuric benzoate
Acetylation	Mercuric chloride
Asphalt	Mercuric salicylate
Benzoates	Mercurophen
Benzoic acid	2, 2'-Methylenebis (4-chlorophenol)
Benzoic acid, sodium-o-ethylmercuri mercapto	Microcrystalline wax
Betanaphthol	p-Nitrophenol
Bismuth benzoate	Paraffin
Borates	Pentachlorophenol or its sodium salt
Boric acid	Phenylmercury acetate
Bromobenzene, mono	Phenylmercury acetate plus calcium carbonate
Bromoform	Phenylmercury acetoxy octadecanoic acid
Calcium propionate	Phenylmercury oleate
Carbon disulfide	Phenylmercury saccharinate
Chloramine-T	o-Phenylphenol
Chlorobenzene, mono	Phenyl salicylate
Chlorocarvacrol	Polyester treatment
Chloroform	Quinoline, 8-hydroxy
Chloronaphthalene	Salicylanilide
Chlorophenol salts	Salicylic acid
Chlorothymol	Silico fluoride, sodium
Chloroxylenols	Styrene
Copper naphthenate	Tetrachloroethane
Copper oleate	Tetrachlorophenol, sodium salt
Copper-8-quinolinolate	Toluol
Copper resinate	Tribromonaphthol
Copper sulfate	Trichlorophenol
m-Cresol, p-chloro-	Vinyl treatment
o-Cresol	Xylol
Creosote with copper oleate	Zinc chloride
Cuprammonium process	Zinc dimethyldithiocarbamate
Dichlorodimethyl succinate	Zinc naphthenate
Formaldehyde	Zinc oleate
GR-S rubber	Zinc resinate
Hexylresorcinol	Zinc sulfate
Hydrogen sulfide	

listed here are but a sampling of the many kinds available for use today.

4-3.4 RODENTS

Rodents damage paper products while gnawing in their search for food. Inasmuch as the paper particles are not swallowed, toxic agents are useless. The most effective preventive has been setting out poisoned bait. Table 4-18 lists several effective baits. Attempts at impregnating materials with a repellent substance and making them impervious to gnawing have met with fair success, but the only highly effective repellent, actidione, is both expensive and highly toxic to man. Table 4-17 describes the habits and locales of several rodents.

4-3.5 SUNLIGHT

Continued exposure to sunlight causes deterioration of the main structural component of paper, cellulose. The rate and severity of deterioration are dependent upon the kind of cellulose used in the paper and the impurities present therein. As far as paper used for packaging material is concerned, however, deterioration by sunlight is a minor problem.

TABLE 4-14
TIME REQUIRED BY CERTAIN INSECTS TO PENETRATE VARIOUS PAPERS AND OTHER BAG MATERIALS[3]

Material(1)	Common Dampwood Termites	Nevada Dampwood Termites
Toweling	3-1/2 hours	3 hours
Asphalt bagging	7 days	8 days
Cellophane No. 300	4 days	5 days
50-lb kraft paper	1 day	1 day
50-lb kraft paper plus 50% sodium silicate solution	5 days	6 days
3/0 flint sandpaper(2)	more than 35 days	more than 35 days
3/0 flint sandpaper(3)	14 days	14 days
Cellophane No. 300 on 0.0006-in. lead foil(4)	more than 35 days	more than 35 days
No. 30 sulfite paper on 0.00035-in. lead foil(5)	10 days	10 days
0.00035-in. lead foil on No. 30 sulfite paper(6)	more than 35 days	more than 35 days

Notes: 1. Thickness, 0.00088 in. 2. Rough side up 3. Smooth side up 4. Foil side up 5. Paper side up 6. Foil side up

TABLE 4-15
INSECTICIDES

Compound	Effective Against
Pyrethrum	All
Rotenone	All
DDT	Roaches, silverfish
Chlordane	All
Methoxychlor	All
Pentachlorophenol	Roaches, termites, firebrats
Tar derivatives	Drywood termites
Kerosene oil	Silverfish
Benezene hexachloride	Drywood termites
Heptachlor	Powder Post & Bark Beetles
Dieldrin	All
Diazinon	Silverfish, Firebrats

TABLE 4-16
REPELLENTS

Compound	Effective Against
Thiocoumarin	Termites
Hexachlorocyclohexane	Termites
DDT	Termites
3,5-dinitro-o-cresol	Termites
Phenothiazine-3, 5-dinitro-o-cresylate	Termites
Phenothiazine	Termites
3,5-dinitro-o-cryslate	Termites
Lindane	Termites
Arason 75 (thiram)	Rodent
TNB-A (chemical)	Rodent
Improved Z.I.P. (ZAC)	Rodent

4-3.6 HIGH TEMPERATURES

Heat alone can weaken paper by altering its chemical structure but the main role of heat under normal circumstances is that of a catalyst in decay caused by micro-organisms and moisture.

4-3.7 CHEMICALS

Most chemical deterioration of paper is due to the sulfur dioxide gas present in industrial atmospheres. (See par. 4-1.2.2.) The acids formed from sulfur dioxide attack the gel-like portion of the fibers but have a minor effect on the cellulose content. Deterioration varies according to the type of paper. Rag ledger paper and highly purified wood-fiber bond papers are least affected.

4-4 DETERIORATION OF PLASTICS

The wide variety of plastics makes it possible to choose a plastic material that is not affected by the particular environment conditions which it encounters. In general, most plastics have good resistance to corrosion and chemical action. Table 4-19 lists various plastics and their resistance to heat, acids and alkalies, organic solvents, and sunlight. The physical properties of plastics will be influenced by such factors as the manufacturing process and the reinforcements or fillers used.

4-4.1 CHEMICALS

Chemical deterioration of plastics results in loss of strength, erosion, warpage, cracking, and loss of transparency. Most physical changes are caused by loss of plasticizer.

The resistance of several plastics to generalized classes of chemicals is given in Table 4-20. The effects of specific chemical solutions upon plastics are detailed in Table 4-21. Table 4-22 illustrates the relatively high resistance of acrylic plastics to various chemical solutions.

4-4.2 MICRO-ORGANISMS

A few plastics are susceptible to microbiological attack, although the deterioration rarely proceeds further than the surface. Table 4-23 lists the relative resistance to micro-organisms of several plastics.

4-4.3 LOW TEMPERATURES

At typical arctic temperatures (-30° to -50°F), there are quite a few varieties of plastics that remain fairly flexible and retain their toughness. For example, in the ethylene polymer group, polyethylene is tough and durable. Its toughness is not seriously affected by low temperature. It remains fairly flexible but begins to stiffen slightly at -30°F and becomes brittle at -94°F. Teflon and many other thermoplastics also maintain satisfactory pliability at low temperatures.

TABLE 4-17
COMMON TYPES OF SMALL RODENTS[3]

Type	Range	Habits
Norway rat	Universal distribution throughout the world	Burrowing rodent; lives close to man; omnivorous
Roof rat	Warm climates, particularly along seacoast and rivers throughout the world	Adept climber, lives in trees and upper portions of buildings; prefers fruits and vegetables
House mouse	Universal distribution throughout the world	Capable of adaptation to wide variety of conditions; lives close to man; almost omnivorous
Wood rat	Mountainous regions of eastern and western North America and Gulf States	Frequents cabins and camps; prefers green vegetation; seldom destructive
Field mouse	Universal throughout grassland areas of the world	Inhabits meadows and semi-swampy grassy areas; constructs distinct trails; feeds on green vegetation and tree roots
Woodland mouse	Practically all North America; similar forms in other countries	Lives in semiwooded areas; primarily a seed eater
Ground squirrel	Present in semiopen areas of western North America and other countries	Burrowing rodent; food includes grains, green vegetation, and insects

TABLE 4-18
TOXIC RODENT BAITS

Substance	Effectiveness
Warfarin	High
Sodium Fluoroacetate	High
Thallium Sulfate	Good
Red Squill	Good
ANTU	Good
Zinc Phosphide	Good
Strychnine	High
Endrin	High

TABLE 4-19
DETERIORATION RESISTANCE OF PLASTICS AND RUBBERS[3]

Material	Water Abs, % (24 hr, on sample 1/8 in. thick)	Heat, °F continuous	Resistance to(1)		
			Acids and Alkalies	Organic Solvents	Sunlight
Phenol-formaldehyde resin cast (no filler)	0.3-0.4	160	F	G	VG
Phenol-formaldehyde resin molded (woodflour filler)	0.3-1.0	300-350	F	E	VG
Phenol-formaldehyde resin molded (mineral filler)	0.01-0.3	230-450	F	E	VG
Phenol-furfural resin (woodflour filler)	0.2-0.6	300	F	E	VG
Phenol-furfural resin (mineral filler)	0.2-1.0	350-400	F	E	VG
Urea-formaldehyde resin (cellulose filler)	0.4-0.8	170	F	VG	E
Melamine-formaldehyde resin (cellulose filler)	0.1-0.6	210-250	G	E	VG
Melamine-formaldehyde resin (asbestos filler)	0.08-0.14	250-400	G	E	VG
Aniline-formaldehyde resin	0.01-0.08	180-190	F	VG	VG
Glyceryl phthalate (alkyd)	--	250	G	G	VG
Silicone rubber (mineral filler)	0.25-1.0	350	VG	VG	E
Ethyl cellulose	0.8-1.8	115-185	VG	widely soluble	VG
Cellulose acetate (molding)	1.9-6.5	140-220	F	widely soluble	VG
Cellulose acetate (high acetyl)	2.2-3.1	150-220	F	widely soluble	VG
Cellulose acetate-butyrate	1.1-2.2	140-220	F	widely soluble	VG
Cellulose nitrate	1.0-2.0	ca. 140	F	widely soluble	VG
Casein plastics	7-14	275	P	E	VG
Shellac compound	--	150-190	VP	G	E
Cold-molded plastics	0.6-0.2	500	F	G	E
Polyvinyl chloride-acetate (rigid)	0.07-0.08	130	E	F	VG(2)
Polyvinyl chloride-acetate (flexible)	0.40-0.65	150	VG	F	VG(2)
Polyvinyl chloride (plasticized)	0.1-0.6	150-175	VG	F	VG(2)
Polyvinylidene chloride (molding)	<0.1	160-200	E	E	VG(2)
Polyvinyl formal	0.6-1.3		G	G	VG(2)
Polyvinyl butyral (rigid)	1.0-3.0	115	G	F	VG(2)
Polyvinyl butyral (flexible)	1.0-2.0		G	F	VG(2)
Polyvinyl carbazole	0.1		G	F	VG(2)
Allyl resins (cast)	0.3-0.44	212	VG	E	VG
Polyester resins (rigid)	0.15-0.60	250	VG	VG	VG
Polyester resins (flexible)	0.1-2.4	250	VG	VG	VG
Polymethyl methacrylate (cast)	0.3-0.4	140-160	VG	F	VG
Polymethyl methacrylate (molded)	0.3-0.4	155-185	VG	F	VG
Polystyrene	0.03-0.05	150-205	G	F	VG
Polyethylene	<0.01	212	E	VG	VG(2)
Polytetrafluoroethylene	0.00	400	E	E	E
Nylon (molded)	1.5	300	F	E	VG
Butadiene-styrene		250-300	VG	G	VG
Butadiene-acrylonitrile		250-300	VG	VG	VG
Polyacrylic ester		250-350	VG	G	VG
Polysulfide		200-300		E	VG
Isobutylene-isoprene			E	VG	E

Notes:

(1) Code: VP = Very poor, P = Poor, F = Fair, G = Good, VG = Very good, E = Excellent

(2) These compounds exhibit this degree of sunlight resistance when they are protected with the proper stabilizers.

4-5 DETERIORATION OF RUBBER

Rubber is subject to deterioration by a variety of chemical, biological, and physical agents often working in concert with each other. The generalized effects of some deleterious agents are shown in Table 4-24. Detailed discussion of their effects are given in pars. 4-5.1 to 4-5.4.

4-5.1 CHEMICALS

The most serious deterioration in rubber is caused by the ozone present in the atmosphere. Ozone causes rubber to become brittle (Figs. 4-2 and 4-3), and may produce fissures over its surface. The severity of attack varies greatly according to the type of rubber. Oxygen has similar effects but they are subordinate in importance to those caused by ozone. Neoprene, butyl, Thiokol, silicone, Hypalon, and polyacrylate rubbers are

more resistant to ozone than polymers based on butadiene or isoprene, such as GR-S, nitrile rubber, or natural rubbers.

Natural rubbers swell when in contact with liquid hydrocarbons such as oil, gasoline, and benzene. Disintegration and aging occur from prolonged contact. Several synthetic rubbers have been developed which are oil-resistant. These products are substituted for natural rubbers when contact with oil or chemicals is expected. Neoprene, Thiokol, butadiene-acrylonitrile vulcanizates, some polyacrylic ester compounds, and chlorinated rubber are often used for these purposes. Table 4-25 lists various rubber compounds and their chemical resistance.

4-5.2 TEMPERATURE EFFECTS

A number of changes take place in rubbers, particularly carbon-based types, under the influence of low temperatures. All of these changes are reversible, however, and the material recovers its original properties as temperatures return to normal. As the temperature is decreased, the rubber becomes more difficult to bend or stretch. Below a certain subzero temperature, this stiffness increases to a maximum, at which the rubber becomes brittle and will shatter under suddenly applied loads. Long time exposure is sometimes accompanied by crystallization and the plasticizer-time effect. Crystallization results in an increase in stiffness but not necessarily in brittleness. The plasticizer-time effect results in a portion of the plasticizer being thrown out of solution, which may result in a loss of flexibility above the brittle temperature and also cause this temperature to be raised. The various commercial rubbers differ appreciably as to the temperature ranges in which they pass through these various stages.

At high temperatures, both natural and synthetic rubbers become gummy, take on a permanent set, and decrease in tensile strength. The temperatures at which various types of rubber become unusable are shown in Table 4-26. The more general effects of heating are included in Table 4-27.

4-5.3 MICRO-ORGANISMS

Certain rubber compounds are susceptible to microbiological deterioration. The reaction is fairly slow, however, and requires an environment containing moisture and warmth. The resistance of several rubbers to attack by micro-organisms is given in Table 4-27.

TABLE 4-20
AVERAGE PROPERTIES OF SOME PLASTIC MATERIALS[3]

Material	Resistance to						
	Weak Mineral Acids	Strong Mineral Acids	Oxidizing Acids	Weak Alkalies	Strong Alkalies	Organic Solvents	Weathering
Acrylic acid resins	G	G	P	G	G-F	P	F
Casein	F	P	P	P	P	F	P
Cellulose acetate	F	P	P	F	P	P	F
Cellulose acetate butyrate	F	P	P	F	P	P	F
Cellulose nitrate (pyroxylin)	F	P	P	F	P	P	P
Ethyl cellulose	F	P	P	G	F	P	F
Phenolics, cast, electrical, and mechanical grades	F	F	F-P	P	P	F	F
Phenolics, laminated, paper-base	G	F	F	P	P	F-G	F
Phenolics, molded, fabric-filled	G	G	P	F	P	G	F
Phenolics, molded, mineral-filled	G	G	P	F	P	G	F
Phenolics, molded, woodflour-filled	F	P	P	P	P	G	F
Styrene resins	G	F	P	G	G	F-P	F
Urea resins	F	P	P	F	P	F	F
Vinyl resins	G	G	F	G	G	F-P	F-P
Vinylidene chloride resins	G	G-F	F	G	F	F-P	G-F
Chemical Properties: P = Poor, F = Fair, G = Good							

TABLE 4-21
EFFECT ON PLASTICS BY IMMERSION FOR 7 DAYS IN CHEMICAL REAGENTS AT 25°C[4]

Item	Urea-Formaldehyde Laminated	Vinyl Chloride-Acetate Resin	Vinyl Butyral Resin	Methyl Methacrylate Resin	Styrene Resin Molded
30% Sulfuric acid	Surface attacked	None	None	None	None
3% Sulfuric acid	Surface attacked	None	Cloudy	None	None
10% Nitric acid	Delaminated	None	Cloudy	None	None
10% Hydrochloric acid	Delaminated	None	Cloudy	None	None
5% Acetic acid	None	None	Cloudy	None	None
Oleic acid	None	None	Tacky	None	None
10% Sodium hydroxide	Surface attacked	None	None	None	None
1% Sodium hydroxide	None	None	Slightly cloudy	None	None
10% Ammonium hydroxide	None	None	Opaque	None	Discolored
2% Sodium carbonate	None	None	Slightly cloudy	None	None
10% Sodium chloride	None	None	None	None	None
3% Hydrogen peroxide	Delaminated	None	Cloudy	None	None
Distilled water	None	None	Cloudy	None	None
50% Ethyl alcohol	None	None	Swollen; rubbery	Slightly swollen	None
95% Ethyl alcohol	None	None	Dissolved	Surface attacked	None
Acetone	None	Dissolved	Swollen; opaque	Dissolved	Dissolved
Ethyl acetate	None	Decomposed	Decomposed	Dissolved	Dissolved
Ethylene chloride	None	Dissolved	Decomposed	Dissolved	Dissolved
Carbon tetrachloride	None	None	Swollen; rubbery	Surface attacked	Dissolved
Toluene	None	Soft, rubbery	Swollen; rubbery	Dissolved	Dissolved
Gasoline	None	None	None	None	Partly dissolved

Item	Phenol-Formaldehyde Molded	Phenol-Formaldehyde Cast	Phenol-Formaldehyde Laminated	Urea-Formaldehyde Molded
30% Sulfuric acid	Surface roughened	None	Edges swollen	Surface roughened
3% Sulfuric acid	Surface roughened	None	Edges swollen	Surface roughened
10% Nitric acid	Surface roughened	None	Edges swollen	Surface roughened
10% Hydrochloric acid	Surface roughened	None	Edges swollen	Surface roughened
5% Acetic acid	None	None	Edges swollen	None
Oleic acid	None	None	None	None
10% Sodium hydroxide	Decomposed	Decomposed	Delaminated	None
1% Sodium hydroxide	Surface roughened	Decomposed	Edges swollen	None
10% Ammonium hydroxide	Surface dulled	Discolored	Discolored edges swollen	None
2% Sodium carbonate	None	Discolored	Discolored	None
10% Sodium chloride	None	None	Edges swollen	None
3% Hydrogen peroxide	None	Discolored	None	Surface dulled
Distilled water	None	None	None	None
50% Ethyl alcohol	None	None	None	None
95% Ethyl alcohol	None	None	None	None
Acetone	None	Softened	Blistered	None
Ethyl acetate	None	None	None	None
Ethylene chloride	None	None	None	None
Carbon tetrachloride	None	None	None	None
Toluene	None	None	None	None
Gasoline	None	None	None	None

TABLE 4-21
EFFECT ON PLASTICS BY IMMERSION FOR 7 DAYS IN CHEMICAL REAGENTS AT 25°C[4]
(Cont.)

Item	Cellulose Nitrate	Cellulose Acetate	Ethyl Cellulose No. 1	Cold-Molded Phenolic	Casein Plastic
30% Sulfuric acid	None	Crazed; softened	None	None	Rubbery
3% Sulfuric acid	None	Swollen	None	None	Swollen; rubbery
10% Nitric acid	None	Decomposed	None	None	Swollen; cracked
10% Hydrochloric acid	None	Decomposed	None	Cracked on drying	Swollen; cracked
5% Acetic acid	None	Swollen	None	None	Rubbery; split
Oleic acid	None	None	Decomposed	None	None
10% Sodium hydroxide	Crazed	Decomposed	None	Decomposed	Decomposed
1% Sodium hydroxide	Crazed	Surface attacked	None	Decomposed	Broken up
10% Ammonium hydroxide	Crazed; discolored	Opaque; soft	None	None	Swollen; split
2% Sodium carbonate	None	Swollen	None	None	Swollen; rubbery
10% Sodium chloride	None	None	None	None	None
3% Hydrogen peroxide	None	None	None	None	Swollen; rubbery
Distilled water	None	None	None	None	Swollen; rubbery
50% Ethyl alcohol	None	Partly dissolved	Swollen; cracked	None	Swollen; rubbery
95% Ethyl alcohol	Dissolved	Partly dissolved	Dissolved	None	None
Acetone	Dissolved	Dissolved	Dissolved	None	None
Ethyl acetate	Dissolved	Dissolved	Dissolved	None	None
Ethylene chloride	Partly dissolved	Soft; swollen	Dissolved	None	None
Carbon tetrachloride	None	None	Dissolved	None	None
Toluene	Partly dissolved	None	Dissolved	None	None
Gasoline	None	None	Swollen; cracked	None	None

4-5.4 SUNLIGHT

Decomposition of rubber by sunlight is due mainly to the blue and ultraviolet wavelengths. These rays cause the rubber to liberate gases as the rubber decomposes. The surface of rubber undergoing solar deterioration exhibits resinification of the surface and an irregular pattern of very fine cracks. The effects of sunlight on various rubbers are included in Table 4-24.

Preventive measures include coloring the rubber to decrease the effect of the damaging wavelengths, application of plastic coatings to tire surface, and incorporation of anti-ozonants to initial rubber formulation. Storage in darkness, however, is the most effective measure.

4-6 DETERIORATION OF TEXTILES

Textiles are subject to deterioration by the principal forces of weather and biological agents. Textiles are particularly susceptible to destruction by micro-organisms since the materials are usually of vegetable or animal origin and, therefore, serve as food.

4-6.1 MICRO-ORGANISMS

Warmth and wetness facilitate the development of a flourishing and diversified collection of bacteria, molds, and fungi which destroy materials of vegetable or animal origin. Fabrics of cotton, linen, and some rayons are vigorously attacked. Microbiological deterioration causes odors, spotting, loss of water repellency, loss of strength, and a decrease in flexibility. The growth of micro-organisms on textiles is invariably preceded by contact with soil or a moist, tropical environment. The relative resistance of various textiles to microbiological attack is shown by Table 4-28. Group I is the most resistant and Group V the least resistant.

The standard preventive is to treat textiles with a fungicide. The fungicides most often employed are copper naphthalate, copper 8-quinolinolate, and 2,2'-

TABLE 4-22
EFFECT OF TOTAL IMMERSION ON ACRYLIC PLASTICS[2]

Solution(2)	% Wt Gain(3)
30% Sulfuric acid	0.6
3% Sulfuric acid	1.0
10% Hydrochloric acid	0.7
10% Sodium hydroxide	0.8
1% Sodium hydroxide	1.0
10% Nitric acid	0.9
5% Acetic acid	1.0
2% Sodium carbonate	1.0
10% Sodium chloride	0.9
10% Ammonium hydroxide	0.9
3% Hydrogen peroxide	1.0
100% Distilled water	0.9

Notes:
(1) Approved tests of the Committee on Plastics of the American Society for Testing Materials using pieces of material 1 x 3 x 0.125 in. totally immersed in the various chemical solutions for 192 hr at 25°C. Data supplied for Plexiglas by Rohm and Haas Co., Philadelphia, Pa.

(2) All concentrations given in percentage by weight in distilled water.

(3) A gain in weight of 1% or less is considered negligible except in unusual applications. None of the above solutions appreciably affects the appearance or strength characteristics.

methylenebis (4-chlorophenol). The last fungicide mentioned is widely used as Compound G-4.

4-6.2 EXCESSIVE DRYING

Generally, moisture is an active chemical and physical agent of deterioration. Ordinarily, the more severe the moisture conditions, the more rapid the degradative effect. But where deterioration of textiles in concerned, there is one peculiar feature worth noting. In a negative sense moisture can contribute to the breakdown of some textiles by its very absence. As for most materials, there is some optimum moisture content for the maintenance of useful properties. Textiles that have lost their properties through lack of humidity can be returned to use if they are returned to the proper humidity.

4-6.3 SUNLIGHT

Sunlight is responsible for most of the nonbiological deterioration of textiles. The deterioration results from changes in the cellulose content of the textile fiber caused by solar radiation. Table 4-29 lists the effects of sunlight on various textile fibers.

Certain dyestuffs reduce the deleterious effects of sunlight. Anthraquinone vat dyes and substantive azo dyes protect cotton, while Monostral Fast Blue protects woven cotton duck. Green, blue, and brown dyes generally retard solar deterioration, whereas orange and yellow dyes generally accelerate deterioration.

Deterioration by sunlight is sometimes accelerated by the effects of the elements. The total effect on textiles exposed to the elements is summarized in Table 4-30.

TABLE 4-23
RESISTANCE OF PLASTICS TO ATTACK BY MICRO-ORGANISMS[3]

Material	Resistance
Acrylics	
Polymethylmethacrylate	Good
Polyacrylonitrile ("Orlon")	Good
Acrylonitrile-vinyl chloride copolymer ("Dynel")	Good
Cellulose derivatives	
Cellulose acetate(1)	Good, poor
Cellulose acetate-butyrate	Good
Cellulose acetate-propionate	Good
Cellulose nitrate	Poor
Ethyl cellulose	Good
Rayons	
Acetate rayon ("Estron")	Good
Saponified acetate rayon	Slightly more resistant than cotton
Cuprammonium rayon	Poor
Viscose rayon	Poor
Phenol-formaldehydes	
Phenol-formaldehyde(2)	Good
Phenol-aniline-formaldehyde	Poor
Resorcinol-formaldehyde	Good
Melamine-formaldehydes	
Melamine-formaldehyde(3)	Good, poor
Urea-formaldehydes	
Urea-formaldehyde(3)	Good
Protein-formaldehydes	
Zein-formaldehyde ("Vicara")	Good
Casein-formaldehyde	Poor
Polyamides	
Nylon(4)	Good
Polyesters	
Ethylene glycol terephthalate ("Terylene") ("Fiber V")	Good
Polyethylenes	
Polyethylene(5)	Good
Polytetrafluoroethylene ("Teflon")	Good
Polymonochlorotrifluoroethylene	Good
Polyisobutylene	Good
Styrenes	
Polystyrene	Good
Polydichlorostyrene	Good
Vinyls and vinylidenes	
Polyvinyl chloride	Good
Polyvinyl acetate	Poor
Polyvinyl chloride-acetate	Good

TABLE 4-23
RESISTANCE OF PLASTICS TO ATTACK BY MICRO-ORGANISMS[3] (Cont.)

Material	Resistance
Polyvinylidene chloride	Good
Polyvinyl butyral	Good
Glyptal resins (Alkyd resins)	Poor, moderate
Silicone resins	Good

Notes:

(1) Fully acetylated cotton is resistant, but there are acetylated cottons in which the percentage of acetate is not high enough to impart complete resistance.

(2) Some cases are on record in which phenol-formaldehydes have been listed as poor. This difference in opinion probably arises from testing samples containing susceptible fillers since the resin itself is considered as having rather good fungus resistance.

(3) White and Siu, in tests on cotton fabrics impregnated with urea-formaldehyde and melamine-formaldehyde resins, found that a high degree of fungal resistance was imparted to the cotton by the resins. It was not conclusively shown, however, whether the resistance was due to the resins as such or to the possible presence of free formaldehyde.

(4) Some tests have indicated nylon to be attacked in soil burial, but most evidence shows it to be immune.

(5) Klemme and Watkins in 1950 reported that the susceptibility of polyethylene and polyisobutylene resins to fungus growth decreases as the average molecular weight increases. Ethylene materials of molecular weights above 10,000, and a butylene sample of 100,000 mw, were found to be fairly resistant. Polytrifluorochloroethylene ("Kel-F") shows a nutritive inertness comparable to the high-molecular-weight polyethylene.

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TABLE 4-24
PHYSICAL PROPERTIES OF SYNTHETIC AND NATURAL RUBBERS[3]

Material	Effect of Heat	Abrasion Resistance	Effect of Sunlight (under tension)	Effect of Aging
Chemigum, oil-resistant	Stiffens	Excellent	Equal to rubber	Stiffens
Chemigum, tire	Stiffens	Good	None	Better than rubber
GR-I (Butyl)	Stiffens slightly	Excellent	None	Highly resistant
GR-M (Neoprene)	Stiffens slightly	Excellent	None	Highly resistant
GR-N (Perbunan)	Stiffens	Excellent	Slight	Highly resistant
GR-P (Thiokol FA)	Hardens slightly	Fairly good	None	None
GR-P (Thiokol ST)	Hardens slightly	Good	None	None
GR-S (Buna S), hard	--	--	--	Highly resistant
GR-S (Buna S), soft	Stiffens	Excellent	Deteriorates	Highly resistant
Hycar OR-15, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-25, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-15, hard	--	--	--	Highly resistant
Hycar OR-10, soft	Stiffens	Excellent	Deteriorates	Highly resistant
Koroseal, soft	Softens	Good	None	Highly resistant
Koroseal, hard	Softens	Excellent	None	Highly resistant
Pliolite, No. 40	Softens	--	None	None
Resistoflex	Softens	Good	None	None
Tygon T	Softens	Good	None	--
Vistanex, medium	--	--	None	Better than rubber
Vistanex, high	--	--	None	Better than rubber
Natural rubber, hard	--	--	--	Highly resistant
Natural rubber, soft	Softens	Excellent	Deteriorates	Moderately resistant

Fig. 4-2. Ozone Deterioration of Rubber Tire

Fig. 4-3. Tire With a Section Protected by Strippable Compound–Other Section (Control) Having No Protection

TABLE 4-25
CHEMICAL RESISTANCE OF NATURAL RUBBER COMPOUNDS[3]

Item	Concentration by Weight	Maximum Temperature, °F	Degree of Vulcanization	Design of Compound
Solutions of Inorganic Acids				
Arsenic acid	Any concentration	150	(Soft	Specific
			(Hard	General
Carbonic acid	Up to saturation at atmospheric pressure	150	Soft or hard	General
Chlorine water (hypochlorous acid)	(Up to saturation at) (atmospheric)	100	Soft	Specific
	(pressure)	150	Hard	Specific
Fluoboric acid	Any concentration	150	Soft or hard	General
Fluosilicic acid	Any concentration	150	Soft or hard	General
Hydrobromic acid	Any concentration	(100	Soft	Specific
		(150	Hard	Specific
Hydrofluoric acid	Up to 50%	150	Soft or hard	General
Hydrogen sulfide water	Up to saturation at atmospheric pressure	150	Hard	General
Hydrochloric acid	Any concentration	150	Soft or hard	General
Phosphoric acid	Up to 85%	150	(Soft	Specific
			(Hard	General
Sulfuric acid	Up to 50%	150	Soft or hard	General
Sulfurous acid	Up to saturation at atmospheric pressure	150	Hard	Specific
Solutions of Inorganic Salts and Alkalies				
Aluminum chloride	Up to saturation	150	Soft or hard	General
Aluminum sulfate	Up to saturation	150	Soft or hard	General
Alums	Up to saturation	150	Soft or hard	General
Ammonium chloride	Up to saturation	150	Soft or hard	General
Ammonium hydroxide	Up to saturation	100	Hard	General
Ammonium persulfate	Up to saturation	(100	(Soft	General
		(150	(Hard	General
Ammonium sulfate	Up to saturation	150	Soft or hard	General
Barium sulfide	Up to saturation	150	Soft or hard	General
Calcium bisulfite	Up to saturation	150	Hard	Specific
Calcium chloride	Up to saturation	150	Soft or hard	General
Calcium hypochlorite	Up to saturation	150	(Soft	Specific
			(Hard	General
Sodium hydroxide	Up to saturation	150	Soft or hard	General
Potassium hydroxide	Up to saturation	150	Soft or hard	General
Copper chloride (cupric)	Up to saturation	150	Hard	General
Copper cyanide (in solution with alkali cyanides)	Up to saturation	150	Soft or hard	General
Copper sulfate (cupric)	Up to saturation	150	Soft or hard	General
Ferric chloride	Up to saturation	150	(Soft	Specific
			(Hard	General
Ferrous sulfate ("copperas")	Up to saturation	150	Soft or hard	General
Nickel acetate	Up to saturation	150	Hard	Specific
Plating solutions: Brass) Cadmium) Copper) Gold) Lead) Nickel) Silver) Tin) Zinc)	--	150	Soft or hard	General
Potassium cuprocyanide	Up to saturation	150	Soft or hard	General
Potassium dichromate	Up to saturation	150	Hard	General
Sodium (or potassium) antimonate	Up to saturation	150	Soft or hard	General
Sodium (or potassium) bisulfite	Up to saturation	150	Hard	General
Sodium (or potassium) acid sulfate	Up to saturation	150	Soft or hard	General
Sodium (or potassium) chloride	Up to saturation	150	Soft or hard	General

TABLE 4-25
CHEMICAL RESISTANCE OF NATURAL RUBBER COMPOUNDS[3] (Cont.)

Item	Concentration by Weight	Maximum Tempera- ture, °F	Degree of Vulcanization	Design of Compound
Solutions of Inorganic Salts and Alkalies (Continued)				
Sodium (or potassium) cyanide	Up to saturation	150	Soft or hard	General
Sodium (or potassium) hypochlorite	Up to saturation	150	(Soft	Specific
			(Hard	General
Sodium (or potassium) sulfide	Up to saturation	150	Soft or hard	General
Sodium (or potassium) sulfite	Up to saturation	150	Soft or hard	General
Sodium (or potassium) thiosulfate	Up to saturation	150	Soft or hard	General
Silver nitrate	Up to saturation	150	Soft	Specific*
Tin chloride (either stannous or stannic)	(Any aqueous solution)	150	(Hard	General
			(Soft or hard	General
Zinc chloride	Up to saturation	150	Soft or hard	General
Zinc sulfate	Up to saturation	150	Soft or hard	General
Organic Materials				
Acetic acid	Any concentration	150	Hard	Specific
Acetic anhydride	--	150	Hard	Specific
Acetone	Any concentration	150	(Soft	Specific
			(Hard	General
Amyl alcohol	Any concentration	150	(Soft	Specific
			(Hard	General
Aniline hydrochloride	Any concentration	150	Soft or hard	General
Butyl alcohol	Any concentration	150	(Soft	Specific
			(Hard	General
Casein	Any concentration	150	Soft or hard	General
Castor oil	--	150	Hard	Specific
Citric acid	Up to saturation	150	Soft	Specific
Coconut oil	--	150	Hard	Specific
Cottonseed oil	--	150	Hard	Specific
Dyestuffs	--	150	Hard	Specific
Ethyl alcohol	Any concentration	150	(Soft	Specific
			(Hard	General
Ethylene glycol	Any concentration	150	Soft or hard	General
Formaldehyde (formalin)	40% aqueous solution	100	Hard	Specific
Formic acid	Any concentration	100	Hard	Specific
Furfural	--	100	Hard	Specific
Gallic acid	Up to saturation	150	Soft or hard	General
Glucose	Any concentration	150	Soft or hard	General
Glue	Any concentration	150	Soft or hard	General
Glycerin	Any concentration	150	Soft or hard	General
Lactic acid	Any concentration	150	Hard	Specific
Malic acid	Up to saturation	150	Soft or hard	Specific
Methyl alcohol	Any concentration	150	(Soft	Specific
			(Hard	General
Mineral oils	--	100	Hard	Specific
Propyl alcohol	Any concentration	150	(Soft	Specific
			(Hard	General
Soaps	Any concentration	150	Soft or hard	General
Tannic acid	Up to saturation	150	Soft or hard	General
Tartaric acid	Up to saturation	150	(Soft	Specific
			(Hard	General
Triethanolamine	Any concentration	150	Soft or hard	General
Vinegar	--	150	Hard	Specific

*If discoloration is to be avoided.

TABLE 4-26
DEGRADATION OF RUBBER BY HIGH TEMPERATURES[5]

Type of Rubber	Highest Usable Temperature, °F (°C)
Silicone	500 (260)
Polyacrylic	350 (177)
Buna-N	340 (171)
Neoprene	315 (157)
Butyl	300 (149)
Buna-S	280 (138)
Natural	260 (127)
Thiokol	250 (121)

TABLE 4-27
RESISTANCE OF NATURAL AND SYNTHETIC RUBBERS TO MICRO-ORGANISMS[3]

Material	Resistance
Natural rubber	
Pure natural rubber—caoutchouc	Attacked
Highly purified natural rubber, 99%+,	
not vulcanized	Attacked
Natural rubber vulcanizate	Attacked
	Resistant
Hevea latex	Attacked
Guayule latex	Attacked
Crude sheet	Attacked
Crepe rubber	Attacked
Pale crepe, not compounded	Attacked
Pale crepe, compounded	Resistant
	Attacked
Plantation crepe	Attacked
Smoked sheet, not compounded	Attacked
Smoked sheet, compounded	Resistant
	Attacked
Reclaimed rubber	Attacked
Gutta-percha	Some attack but less
	than natural rubber
Chlorinated rubber	Resistant
Synthetic rubbers	
Neoprene-polychloroprene,	Resistant
not compounded	Attacked
Neoprene, compounded(1)	Resistant
	Attacked
GR-S, butadiene-styrene,	Resistant
not compounded	Attacked
GR-S, butadiene-styrene,	Resistant
compounded(2)	Attacked
GR-S, butadiene-styrene, compounded,	
acetone extracted	Resistant
Buna-S, butadiene-styrene, uncured	Attacked
"Hycar OR," butadiene-acrylonitrile,	Attacked
not compounded	
"Hycar OR," butadiene-acrylonitrile,	Resistant
compounded	Attacked
Buna N, butadiene-acrylonitrile,	Attacked
compounded	
GR-I (butyl), isobutylene-isoprene,	Resistant
uncured	Attacked
GR-I (butyl), isobutylene-isoprene,	Resistant
compounded	Attacked
"Thiokol", organic polysulfide, uncured	Attacked
"Thiokol", organic polysulfide,	Resistant
vulcanized	
"Thiokol", organic polysulfide, sheets	Attacked
for gasoline tank linings	
Silicon rubber	Resistant
Experimental elastomers from:	
Butadiene	Attacked
Isoprene	Attacked
Isobutylene	Attacked
Acrylonitrile	Attacked
Styrene	Attacked

Notes:

(1) Neoprene containing nutrients may be attacked, but the hydrocarbon itself is not attacked.

(2) This sample produced by improved processing to give fungal resistance.

TABLE 4-28
RELATIVE RESISTANCE OF VARIOUS FIBERS TO MICROBIOLOGICAL DECOMPOSITION[3]

Group	Fibers	
	Resistance to Fungal Decomposition	Resistance to Bacterial Decomposition
I	Coir	Coir
II	Tossa jute and raw cotton	Manila and sisal
III	Hemp, manila, viscose rayon, mestha, white jute, and aloe	Hemp, green hemp, and ramie
IV	Ramie and sisal	Flax, New Zealand hemp, aloe, tossa jute, and white jute
V	Green hemp, New Zealand hemp, and flax	Mestha, viscose rayon, and raw cotton

TABLE 4-29
EFFECT OF SUNLIGHT ON FIBERS[3]

Fiber	Type of Chemical	Reported Effect[(a)]	Reported Effect[(b)]	Reported Effect[(c)]
Cotton	Cellulosic	Loss of strength, tendency to yellowing	Loss of tensile strength, tendency of white to yellow	--
Silk	Protein	--	Loss of tensile strength, affected more than cotton	--
Wool	Protein	Loss of strength, some effect on dyeing properties	Loss of tensile strength, dyeing affected, less affected than cotton	--
Viscose rayon	Regenerated cellulose	Loses tensile strength after prolonged exposure, very light discoloration	Loss of tensile strength	Loss of strength with direct exposure but superior to acetate
Cuprammonium rayon	Regenerated cellulose	Loses strength on prolonged exposure	Loss of tensile strength	--
Acetate	Cellulose acetate	Slight loss of tensile strength. No discoloration	Loss of tensile strength	Loss of strength with direct exposure
Nylon	Adipic acid and hexamethylene diamine	Loses strength on prolonged exposure. No discoloration. Bright yarn more resistant than semi-dull	Some loss of tensile strength, no discoloration	Slow loss of strength with direct exposure
"Bobina-Perlon"	Caprolactam	--	--	Similar to nylon[(1)]
"Rhovyl"	Vinyl chloride	--	--	Not degraded[(2)]
"Thermovyl"	Vinyl chloride	--	--	Not degraded[(2)]
"Vinyon"	Vinyl chloride and vinyl acetate	None	None	Not degraded
"Saran"	Vinyl chloride and vinylidene chloride	Darkens slightly	Darkens slightly	--
"Velon"	Vinyl chloride and vinylidene chloride	--	Darkens slightly	--
"Tygan"	Vinyl chloride and vinylidene chloride	--	--	Not degraded[(3)]
"Dynel"	Vinyl chloride and acrylonitrile	Darkens somewhat after prolonged exposure with some loss of tensile strength	Some loss of tensile strength	Not degraded
"Vinyon N"	Vinyl chloride and acrylonitrile	Darkens somewhat after prolonged exposure with some loss of tensile strength	Darkens slightly, some loss of tensile strength	--
"Orlon"	Acrylonitrile	Very resistant to degradation by ultraviolet light and atmosphere	Very high resistance to sunlight deterioration	Not degraded
"Acrilan"	Acrylonitrile	Very resistant to degradation by ultraviolet light and atmosphere	--	--
"X-51"	Acrylic ester	--	--	Not degraded
"Dacron"	Terephthalic acid and ethylene glycol	Loss of strength on prolonged exposure. No discoloration. Much more resistant behind glass than in direct sunlight	Some loss in strength. No discoloration. Much more resistant behind glass than in direct sunlight	--
"Terylene"	Terephthalic acid and ethylene glycol	--	--	Very slow loss of strength with direct exposure
--	Polyethylene	Prolonged exposure decreases tensile strength	Some loss of tensile strength for clear, much less for pigmented. No darkening	
Polythene	Polyethylene	--	--	Very slight degradation[(4)]

TABLE 4-29
EFFECT OF SUNLIGHT ON FIBERS[3] (Cont.)

Fiber	Type of Chemical	Reported Effect[(a)]	Reported Effect[(b)]	Reported Effect[(c)]
"Azlon"	Protein	Very slow deterioration and loss of strength	--	--
"Vicara"	Protein	--	Slow deterioration and loss of strength	--
"Ardil"	Protein	--	--	Very slow loss of strength with direct exposure[(5)]
Glass	Inorganic	None	None	Not degraded
Asbestos, chrysotile	Inorganic	--	--	Not degraded

Notes:
(a) Textile World's Synthetic-Fiber Table, 1951
(b) Modern Plastics Encyclopedia and Engineer's Handbook, 1952
(c) The Rubber Age and Synthetics, May 1953

(1) Also named "Rilsan," "Grillon," "Phrilon"
(2) Also named "Pe Ce," "Isovyl," "Fibrovyl"
(3) Also named "Lumite," "Parmalon," "Harlon"
(4) Also named "Courlene"
(5) Also named "Lanital"

TABLE 4-30
RESISTANCE OF FIBERS TO OUTDOOR EXPOSURE[3]

Fiber	Resistance to Outdoor Exposure
Viscose rayon	Yellows slightly
Cuprammonium rayon	Good
Acetate	Loses strength somewhat
Nylon	Excellent
"Vinyon N" or "Dynel"	Excellent
"Saran" or "Velon"	Excellent
"Orlon" and "Chemstrand"	Excellent
"Dacron" or "Terylene"	Excellent
"Acrilan"	Excellent
Glass	Excellent

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CHAPTER 5

CLEANING AND DRYING

5-1 GENERAL

To obtain maximum benefits from the various preservation and packaging methods, the item must be perfectly clean in order to prevent any chemical action that might result in corrosion or other forms of deterioration. Because cleaning is the first step in the process of preservation and packaging, it must be performed thoroughly to insure both the effectiveness of the subsequent operations and the usefulness of the packaged item.

Five general requirements for cleaning are:

(1) It must be thorough.

(2) Process must not injure item.

(3) Disassembly should be limited.

(4) Fingerprints must be removed from critical surfaces.

(5) Items must pass required tests.

The purpose of this chapter is to aid the packaging engineer in prescribing and designating cleaning and drying methods and materials. MIL-P-116 (Ref. 1) establishes the basic cleaning requirements to be met when packaging for the military and gives information on the techniques and equipment to be used with the cleaners and cleaning processes covered. Fig. 5-1 lists the considerations involved when prescribing a cleaning process and cleaner.

5-2 CONTAMINATION

Water soluble, oily, and solid contaminants which are commonly deposited on military items being packaged include fingerprints and perspiration, inorganic residues, organic residues, and water or other liquids (Fig. 5-2). Table 5-1 lists the cleaners that are most frequently used to remove these contaminants.

5-3 CHOOSING A CLEANING PROCESS AND CLEANER

MIL-P-116 lists the specifications covering the cleaners that may be used for each cleaning process. Uncommon design characteristics of the item, however, may require a cleaning procedure not contained in MIL-P-116.

5-3.1 ITEM CONSIDERATIONS

a. *Material Composition.* No adverse interaction may occur between the item and the cleaner. For example, petroleum solvent cleaning (process C-3) should not be used for cleaning natural rubber because the solvent would deteriorate the rubber.

b. *Portion or Area Requiring Cleaning.* When only portions of an item require cleaning, either the entire item or just the critical surfaces may be subjected to the cleaning process. In either case, the cleaner and process selected must not adversely affect any of the materials of which the item is made.

c. *Complexity of Construction.* If it is feasible, complex items should undergo some disassembly before cleaning. In all cases, the selected cleaning process must adequately clean all protrusions, crevices, and grooves; the cleaner should either not collect in grooves or crevices, or be easily removed from such places if it does collect.

5-3.2 CLEANING PROCESS CONSIDERATIONS

a. *Special Equipment Required.* The packaging engineer must be aware of all special equipment required when prescribing a particular cleaning process. Special equipment used must not harm the item or unduly increase the cleaning costs.

b. *Availability of Special Equipment.* If special equipment is required, it must be available at the cleaning location to be suitable for use with the particular item being cleaned, or be capable of being adapted or

modified so as to be suitable for use with the item. If the required equipment is not available, the desirability of using the particular process must be weighed against the cost and possible delay in obtaining the equipment.

c. *Hazards to Personnel.* Packaging engineers should not overlook the problems associated with hazardous cleaning processes (and cleaners). Considerations involved include costs of special protective equipment or devices, personnel training required, insurance costs, the time factor involved, and possible residual hazards.

5-3.3 CLEANER CONSIDERATIONS

a. *Type and Degree of Contamination.* The cleaner selected should be effective, economical, and suited to the particular residue being removed. Packaging engineers should become familiar with the chemical characteristics of cleaners under consideration. Associated information concerning the item must also be available for checking on compatibility.

b. *Conformance to Specifications.* All cleaners must conform to Federal or Military Specifications. However, if an acceptable cleaner is not available or if an item requires special attention, deviations may be made. Substitutes for those cleaners covered in MIL-P-116 must be compatible with the item to be cleaned.

c. *Availability of Cleaners.* The availability of the cleaner and other required reagents must be ascertained before a decision is made for use.

d. *Method of Application.* In many cases, the choice of a cleaning process establishes the method of application. In other instances, material composition of the part or its configuration may dictate the manner in which the cleaner is to be applied. In any case, the method used must accomplish cleaning of all required portions of the item without adversely affecting the item.

e. *Removing Cleaner Residues.* Cleaning should be carried out in a manner which leaves no residual clean-

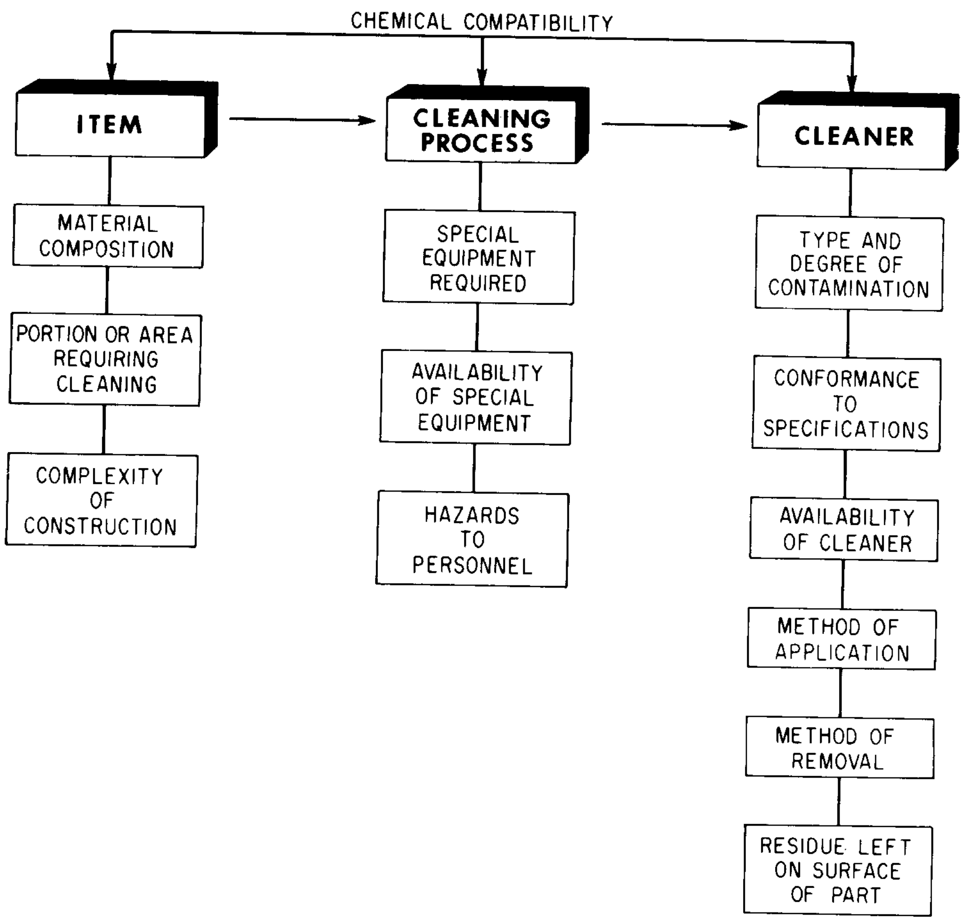

Fig. 5-1. Choosing a Cleaning Process and Cleaner

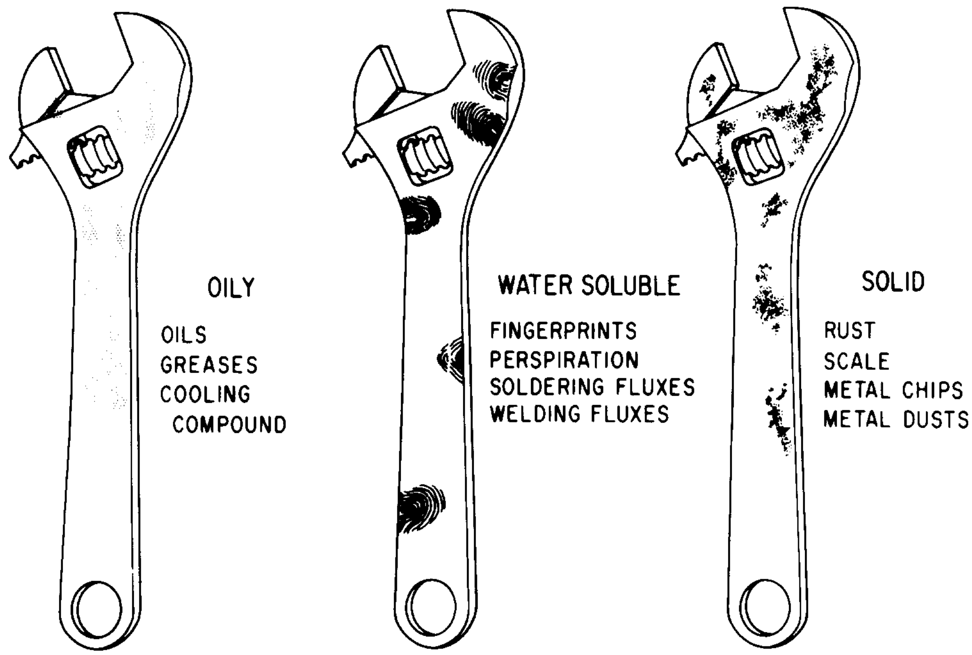

Fig. 5-2. Types of Contaminants

ing material. In those instances where some cleaning residue remains, e.g., on a complex item that cannot undergo disassembly, care should be taken that the cleaner is of a type that will not cause subsequent corrosion of the item or will not reduce the effectiveness of any preservative that might be used on the item. On highly critical surfaces, the cleaner selected should always be of a type that leaves no residue. The best way of meeting and overcoming such situations is through early consultation with item design personnel.

5-4 CLEANER SELECTION CHART

Table 5-2 presents data to aid in the selection of an appropriate cleaning process and cleaner for a particular application. All of the cleaning processes specified in MIL-P-116 are listed in the table, along with the various cleaners that may be used with each process. Data are also included on the characteristics and uses of each cleaner, as well as on any special considerations involved, such as hazards to personnel.

It should be noted that in some cases the specifying of cleaning requirements involves more than just selecting a cleaning process and a cleaner, e.g., an item that must be cleaned and packaged in a dust-free environment, thus necessitating the use of special "clean room".

The advent of sophisticated subassemblies and components for aerospace and other modern military applications has created new requirements for absolute cleanliness in assembly and packaging operations. With tolerances often held to within millionths of an inch, contamination, even in minute quantities, may cause malfunctions. To avoid such contamination, precise assembly work must be performed in a controlled environment or "clean room". Air entering the room is filtered and conditioned to control its oil and moisture content, thus creating favorable environmental conditions in the clean room (Ref. 2).

Micro-miniaturized components and subassemblies go through rigid cleaning procedures before entering the clean room for final assembly and packaging. Procedures entail cleaning in ultrasonic baths or spray cleaning with solvents to remove contaminants.

5-5 CLEANING PROCEDURES FOR SPECIAL ITEMS

For some special types of items, specific cleaning procedures are covered in specifications. These procedures may give complete cleaning instructions, or may augment and supplement MIL-P-116. For example, the cleaning of optical elements and lenses is covered in MIL-P-14232 (Ref. 3). Fig. 5-3 illustrates cleaning processes for the removal of perspiration and fingerprints,

TABLE 5-1
SPECIFIC CLEANERS FOR VARIOUS TYPES OF CONTAMINATION

Type of Contamination	Type of Surface	Cleaner Specification
Fingerprints and perspiration	Metal surfaces	MIL-C-15074, *Corrosion Rreventive, Fingerprint Remover*
Organic residues		
Oils and greases	Metal surfaces	O-T-236, *Tetrachloroethylene (Perchloroethylene), Technical*
Oils and greases	Metal surfaces	O-T-634, *Trichloroethylene, Technical*
Carbon	Metal surfaces	MIL-G-5634, *Grain, Abrasive, Soft, for Carbon Removal*
Oils, greases, asphalts, and tars	Copper alloys (brass, bronze) and ferrous surfaces	MIL-C-20207, *Cleaning Compound, Solvent, Grease Removal, Heavy Duty*
Oils, greases, asphalts, and tars	Metallic and painted surfaces	MIL-C-11090, *Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying*
Inorganic residues		
Rust removal	Ferrous metal surfaces	MIL-C-14460, *Corrosion Removing Compound, Sodium Hydroxide Base; for Electrolytic or Immersion Application*
Soils	Ferrous metal surfaces	P-C-535, *Cleaning Compound, Platers' Electrocleaning, for Steel*
Grease, oil, dirt	Various surfaces, if compatible	P-C-444, *Cleaning Compound, Solvent, Grease Emulsifying*
All contamination		
Rust removal and metal etch conditioning	Metal surfaces	MIL-M-10578, *Metal Conditioner and Rust Remover (Phosphoric Acid Base)*

TABLE 5-1
SPECIFIC CLEANERS FOR VARIOUS TYPES OF CONTAMINATION (Cont.)

Type of Contamination	Type of Surface	Cleaner Specification
Preparation prior to application of organic or inorganic surface castings.	Aluminum, magnesium, and other metallic surfaces	MIL-M-7752, *Metal Cleaner Silicate-Soap*
Cleaner as brightner - aircraft	Aluminum surfaces	MIL-C-5410, *Cleaning Compound, Aluminum Surface, Non-Flame-Sustaining*
	Aircraft metal parts	MIL-C-5543, *Cleaning Compound, Washing Machine, Aircraft Metal Parts*
	Ferrous and non-ferrous alloy parts	P-C-436, *Cleaning Compound Alkali, Boiling Vat (Soak) or Hydrosteam*
	Ferrous and non-ferrous surfaces	P-C-437, *Cleaning Compound, High Pressure (Steam) Cleaner*

and in the use of petroleum solvents. Before choosing a cleaner and cleaning process from MIL-P-116, first determine that a specific cleaning process for the item does not exist.

5-6 TESTING OF CLEANLINESS

To insure that all contamination has been removed, the item should be tested immediately after cleaning. Tests performed may include visual tests, cloth tests, litmus tests, or any other test specified by the packaging engineer to determine if the item has been cleaned effectively. Information on the performance of these tests is contained in MIL-P-116. In performing the tests, care must be exercised to insure that the item is not recontaminated.

5-7 DRYING

Items should be dried immediately after it has been determined that they are clean. Drying processes and the consideration to be observed in their use are given in Table 5-3. Typical drying procedures are illustrated in Fig. 5-4.

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TABLE 5-2
CLEANER SELECTION CHART

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (C-1)*	MIL-C-20207 CLEANING COMPOUND, SOLVENT, GREASE REMOVAL, HEAVY DUTY	Grease removal solvent of organic composition	When the compound is diluted 1 to 1 by volume with distilled water at 25°C it shall have a pH of not less than 11.0	Removal of oil, grease, asphalt, tar, and some rust preventive compounds from ferrous and copper alloy surfaces. Not designed for the removal of rust or corrosion. Do not use on aluminum or zinc.
	MIL-C-5410 CLEANING COMPOUND, ALUMINUM SURFACE, NON-FLAME-SUSTAINING			
	Type I	Nonflammable; phosphoric-acid base; Viscous emulsion used full strength	Viscosity: 120 ± 1 Krebs Unit (K.U.) Phosphoric-acid content (P_2O_5): ≤5.5% by weight	Overhaul of unfinished aluminum surfaces.
	Type II	Nonflammable; Phosphoric-acid base; Clear liquid used full strength or diluted with mineral spirits and water	Phosphoric-acid content (P_2O_5): ≤14.7% by weight	Maintenance of transport aircraft.
	MIL-D-16791 DETERGENT, GENERAL PURPOSE LIQUID, NONIONIC		Cloud point: 120° to 190°F	Preparation of cleaning solutions effective in and rinsable with either fresh or sea water.

* C-Numbers refer to Cleaning Methods as defined in latest revision of MIL-P-116

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (C-1)* (Continued)	MIL-D-16791 DETERGENT, GENERAL PURPOSE LIQUID, NONIONIC (Continued)			
	Type I	Water-soluble Clear liquid	pH: 6.0 to 8.0 at 25°C Saponification No. 5	
	Type II	Oil-soluble		
	MIL-M-7752 METAL CLEANER SILICATE-SOAP	Granular powder	Sodium metasilicate- (40.5 to 41.5%) Sodium trisilicate- (53.5 to 54.5%) Synthetic Soap- (4.9 to 5.1%) pH: 11.0 to 12.5	Cleaning of aluminum, magnesium, and other metallic surfaces.
	MIL-M-10578 METAL CONDITIONER AND RUST REMOVER (PHOSPHORIC ACID BASE)		All types; Flash point (min) 135°F (57°C)	Rust remover for ferrous metal parts and as metal conditioners for ferrous and nonferrous metals prior to application of paints and/or corrosion preventives.
	Type I	Wash-off	Phosphoric acid; 68 g/100ml minimum	
	Type II	Wipe-off	Phosphoric acid; 20-25 g/100ml	

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (C-1)* (Continued)	MIL-M-10578 METAL CONDITIONER AND RUST REMOVER (PHOSPHORIC ACID BASE) (Continued)			
	Type III	Inhibited	Phosphoric acid; 49 g/100ml minimum	
	Type IV	Nonfoaming	Phosphoric acid; 68 g/100ml minimum	
	Type V	Immersion-tank	Phosphoric acid; 68 g/100ml minimum	
	MIL-C-14460 CORROSION REMOVING COMPOUND, SODIUM HYDROXIDE BASE; FOR ELECTROLYTIC OR IMMERSION APPLICATION	Supplied in the form of dry, fine granular, or dry, fine, flake material.		Removal of rust and scale from iron and steel surfaces.
	Type I		Type I Trisodium salt of N-Hydroxyethylenediaminetriacetic acid-13% Min. Sodium Gluconate - 25% min. Sodium Hydroxide - 54% max. Others 7.0% max.	
	Type II		Type II Chelate or Sequestrant Compound 25 to 35% Sodium Hydroxide 35% min. Sodium Cyanide 25 to 35% Others including foamers 4% max.	Type II contains sodium cyanide and is, therefore, classified as poisonous.

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (C-1)* (Continued)	MIL-C-11090 CLEANING COMPOUND, DEGREASING AND DE-PRESERVING SOLVENT, SELF-EMULSIFYING	Self-emulsifying degreasing solvent	Flash point (min): 100°F (38°C) Viscosity(Centistokes) max: 15.0 at 10°F. Emulsion stability (10 parts compound to 90 parts water, for a minimum of 6 hrs)	Removal of oils, greases, asphalt tar, and rust preventive compounds from metallic and painted surfaces. Do not use for removal of wax-type rust preventive compounds.
Dry Cleaning Solvent (C-3)	P-D-680 DRY, CLEANING SOLVENT			Cleaning of metal parts.
	Type I	100°F Solvent (Stoddard Solvent)	Flash point (min): 100°F Distillation Range: Min. 50% distilled: 350°F End point (max): 410°F	Surfaces where tolerances are critical. Cleaning of metal parts prior to plating, painting, or preservation. Used in spray, brush and dip-soak operations. Deteriorates natural and some synthetic rubbers.
	Type II	140°F Solvent	Flash point (min): 138°F Distillation Range: Init Boiling Pt. (min): 350°F Min 50% distilled: 375°F	

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Dry Cleaning Solvent (C-3) (Continued)	P-D-680 SOLVENT, DRY CLEANING (Continued)		End Point (max): 415°F	
	TT-T-291 THINNER; PAINT VOLATILE SPIRITS (PETROLEUM-SPIRITS)	Petroleum distillate	Grade 1 Aniline point: 43° to 59°C (110° to 138°F)	Used as thinners and/or solvents for paints.
	Grade 1	Light thinner	Flash point: 38°C (100°F) Distillation: Init Boiling Point: 150°C (302°F) 90% (by volume): 200°C (392°F) End point: 210°C (410°F)	Used to remove P-type preservatives from metallic surfaces.
	Grade 2	Heavy thinner	Grade 2 Aniline Point: 43° to 65°C (110°F to 149°F) Flash Point: 51.5°C min (125°F) Distillation: Initial Boiling Point: 171°C (340°F) minimum 95% (by volume): 238°C (460°F) maximum	

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Dry Cleaning Solvent (C-3) (Continued)	TT-T-291 THINNER; PAINT VOLATILE SPIRITS (PETROLEUM-SPIRITS) (Continued)		End Point: 251.5°C (485°F) maximum	
	MIL-C-4036 CLEANER, VAPOR PRESSURE, SPRAY RINSE			Used as a portable combination vapor and high-pressure rinse, gasoline-engine-operated cleaner.
	Style 1	Mounted on 4 industrial-type, pneumatic tired wheels. with towing handle, designated Type B-2C		Intended for use in washing and cleaning of aircraft engines and accessories, vehicles, and miscellaneous ground equipment.
	Style 2	Mounted on a 2-wheel, automotive-type trailer, with tow-bar and a folding leg for balance.		
	MIL-D-12491 DEGREASERS, SOLVENT, TANK IMMERSION	Mechanized method and apparatus for applying solvents		Used for removal of grease and dirt from parts associated with maintenance shop operation.
Petroleum Solvent Cleaning (C-5) followed by finger-print removal	ITEMS SHALL BE CLEANED IN ACCORDANCE WITH PROCESS C-3 FOLLOWED BY PROCESS C-8			

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaning Characteristics	Chemical Properties	General Uses and Special Considerations
Vapor Degreasing (C-7)	O-T-634 TRICHLOROETHYLENE, TECHNICAL Type II	Vapor Degreasing	Distillation Range: Initial boiling point (min): 86.0°C Minimum 95 percent distilled (max): 87.5°C Dry point (max): 90.0°C(194.0°F)	Vapor degreasing of metals. Adequate ventilation required for use. Extreme care must be exercised when used. Proper equipment required.
	O-T-236 TETRACHLOROETHYLENE (PERCHLOROETHYLENE) TECHNICAL	Vapor Degreasing	Specific gravity: 1.620 - 1.630 Acidity .0005% Distillation Range: Init Boiling Point: 120°C End Point: 1.22°C (251.6°F)	Removal of oil, grease, and similar contaminants. Vapor degreasing. Adequate ventilation required for use. Temperature at which solvent is used must not injure item.
Perspiration and Fingerpring Removal (C-8)	MIL-C-15074 CORROSION PREVENTIVE, FINGERPRINT REMOVAL		Flash point 100°F (min) Viscosity: 30 centistokes (max) at 100°F.	Fingerprint contamination removal for metallic items. Corrosion preventive for metal parts. Removal of fresh fingerprint residues. Suppression of corrosion that has developed as a result of fingerprint residues. Must be followed by a thorough rinse in P-D-680 or TT-T-291 grade 1.

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Alkaline Cleaning (C-9)	MIL-C-5543 CLEANING COMPOUND, WASHING MACHINE, AIRCRAFT METAL PARTS.		pH (1% solution): 11 to 12 at 25°C	Use in industrial spray washing machines. For cleaning of aircraft metal parts. Must not come in contact with personnel. Used where foaming is objectionable.
Hot Soak Tank Cleaning (C-9)	P-C-436 CLEANING COMPOUND, ALKALI, BOILING VAT (SOAK) OR HYDRO-STEAM	Alkali Cleaning Compound Granular, Free flowing, uniform	Sodium metasilicate anhydrous 31.3% Primary sodium phosphate 12.3% Trisodium phosphate 24.8% Nonionic surfactant 7.9% Anionic surfactant 23.7%	Hot soap tank cleaning of ferrous and nonferrous alloy parts. Removal of asphalt, mineral oil, grease, and road dirt from metal parts.
Immersion in solution electrically charged. (C-11)	P-C-535 CLEANING COMPOUND, PLATERS' ELECTRO-CLEANING, FOR STEEL	Heavy-Duty Anodic Electrocleaner	Composition: Silicate (SiO_2): 10-35% Phosphate (P_2O_5): 5% min.	Removal of soils from ferrous metallic surfaces before electroplating.

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Immersion in solution electrically charged. (C-11) (Continued)	P-C-535 CLEANING COMPOUND, PLATERS' ELECTRO-CLEANING, FOR STEEL. (Continued)		Organic detergent: 0.4% min. Caustic soda: remainder	
Immersed in Emulsion (C-12)	P-C-444 CLEANING COMPOUND, SOLVENT, GREASE EMULSIFYING	Solvent Emulsifying Type Cleaning Compound	Flash point: 110°F (43°C) Pour point(max): 35°F (2°C)	Removal of grease, oil, dirt, by solvent action.
	Type 1	Nonphenolic		General cleaning.
	Type II	Phenolic		Heavy duty - extreme caution.
Steam generated by a steam cleaning machine (C-14)	P-C-437 CLEANING COMPOUND, HIGH PRESSURE (STEAM) CLEANER		Manufacturers' discretion with the exception prohibitions detailed in the specification. pH: 10.5 to 11.4 (½% solution at 25°C)	Cleaning of ferrous and nonferrous surfaces.
Abrasive Blast (C-15)	MIL-S-851 STEEL GRIT, SHOT, AND CUT WIRE SHOT; AND IRON GRIT AND SHOT - BLAST CLEANING AND PEENING	Grit and Shot Type IA - Cast steel Type IB - Steel cut wire (shot only) Type II - Cast iron	Grit Grade A - for special blast cleaning. Grade B - for gen. blast cleaning. Shot Class 1 - for peening Class 2 - for cleaning	Used for blast cleaning of castings and forgings, and for removal of sand, slag, rust, and marine incrustations.

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Abrasive Blast (honing process) (C-16)	CLEANING SHALL BE EFFECTED BY SUBJECTING THE ITEM TO A HIGH VELOCITY STREAM OF ATOMIZED WATER COMBINED WITH A FINE PARTICLE SIZE ABRASIVE AND SUITABLE CORROSION INHIBITOR.			
Soft Grit Blast (C-17)	MIL-G-5634 GRAIN, ABRASIVE, SOFT, FOR CARBON REMOVAL			
	Type I	Apricot Pits	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	Removal of carbon from metal surfaces. Used in blasting machines.
	Type II	Pecan shells	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type III	Black walnut shells	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type IV	Corn Cobs	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Soft Grit Blast (C-17) (Continued)	MIL-G-5634 GRAIN, ABRASIVE, SOFT, FOR CARBON REMOVAL (Continued)			
	Type V	Rice Hulls	Water Content - 10% (max.) Specific gravity - 1.1 to 1.55	
	Type VI	Coconut shells	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type VII	Peach Pits	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type VIII	Filbert shells	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type IX	Cherry pits	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	
	Type X	Almond shells	Water Content - 10% (max.) Specific gravity - 1.2 to 1.4	

TABLE 5-2
CLEANER SELECTION CHART (Cont.)

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Vapor Degreasing followed by finger-print removal (C-18)	ITEMS SHALL BE CLEANED IN ACCORDANCE WITH PROCESS C-7 FOLLOWED BY C-8			

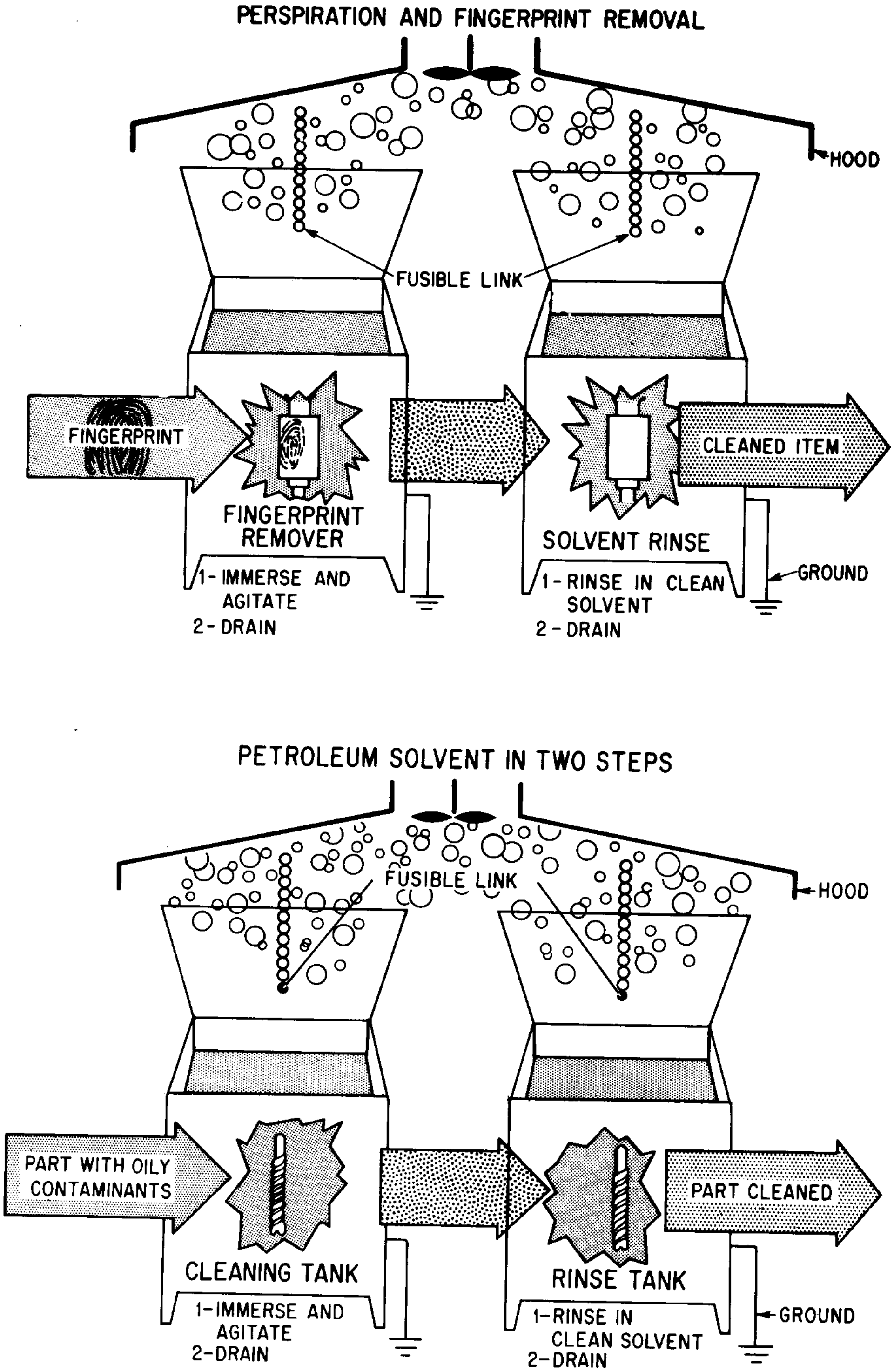

Fig. 5-3. Cleaning Processes

TABLE 5-3
DRYING METHODS AND PROCEDURES

Drying Process	Procedure	Special Considerations
Prepared compressed air (D-1)	Item is subjected to a blast of clean, dry compressed air.	Air must reach all portions of item requiring drying. Any obstructions to air flow must be removed or bypassed. Air must not spray cleaner residue on incompatible portion of item.
Oven (D-2)	Item is dried within a ventilated and temperature-controlled oven.	Items must not be adversely affected by heat.
Infrared lamps (D-3)	Item is exposed to heat rays from a bank of infrared lamps.	Item must not be adversely affected by heat resulting from the infrared radiation.
Wiping (D-4)	Item is wiped with a clean, dry lint-free cloth.	Cloth must be changed when it becomes damp or slightly contaminated.
Draining (D-5)		Used when the final step in cleaning is a petroleum solvent, or when cold application solvent cutback preservatives are employed.

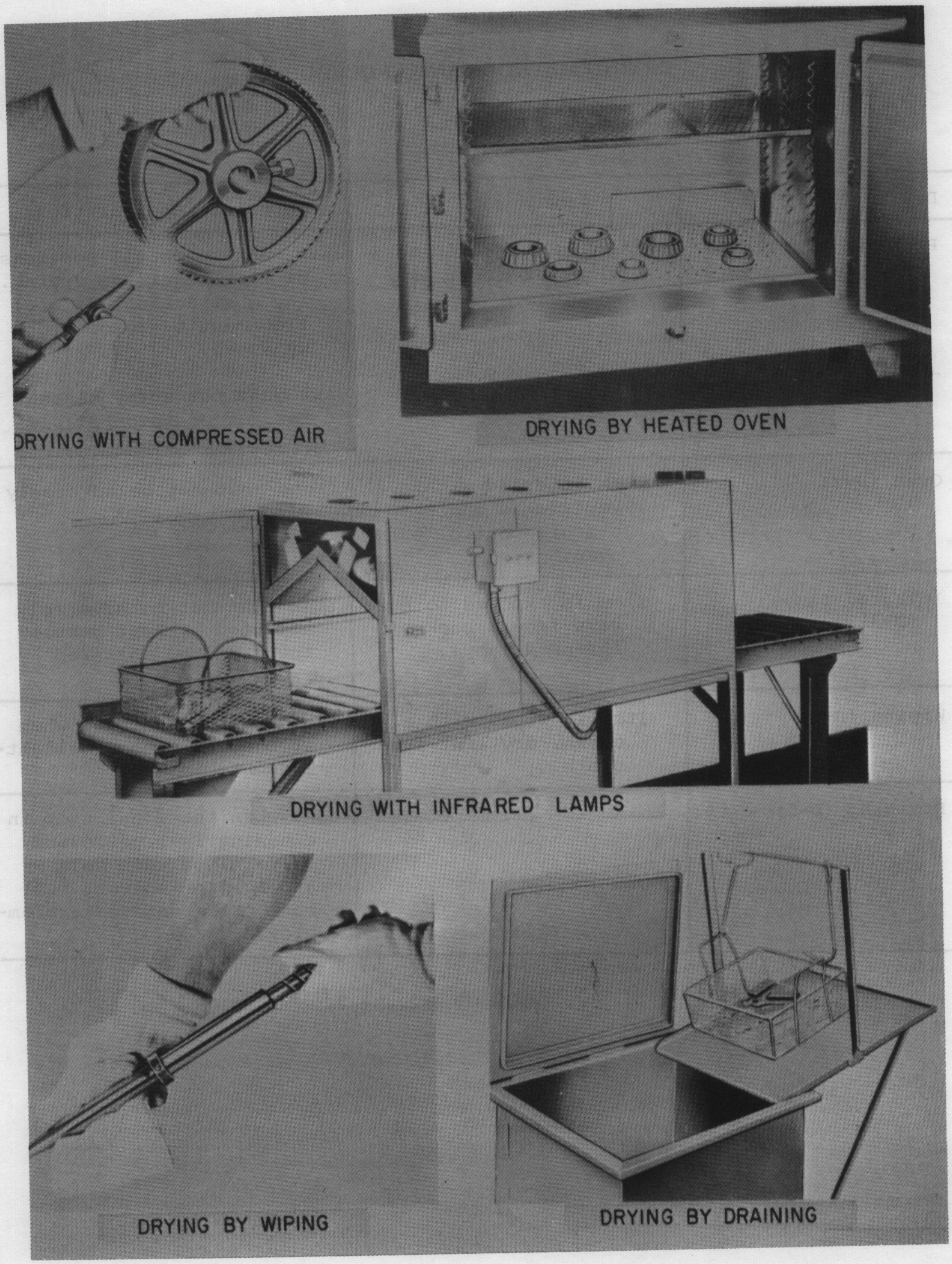

Fig. 5-4. Typical Drying Procedures

REFERENCES

1. MIL-P-116, *Preservation, Methods of.*
2. MIL-STD-1246, *Product Cleanliness Levels and Contamination Control Program.*
3. MIL-P-14232, *Parts, Equipment, and Tools for Ordnance Materiel, Packaging of.*

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MIL-C-15074, *Corrosion Preventive, Fingerprint Remover.*

P-T-634, *Trichloroethylene, Technical.*

MIL-G-5634, *Grain, Abrasive, Soft for Carbon Removal.*

MIL-C-20207, *Cleaning Compound, Solvent, Grease Removal, Heavy Duty.*

MIL-C-11090, *Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying.*

MIL-C-14460, *Corrosion Removing Compound, Sodium Hydroxide Base; for Electrolytic or Immersion Application.*

P-C-535, *Cleaning Compound, Platers' Electrocleaning, for Steel.*

P-C-444, *Cleaning Compound, Solvent, for Grease Emulsifying.*

MIL-M-10578, *Metal Conditioner and Rust Remover (Phosphoric Acid Base).*

MIL-M-7752, *Metal Cleaner, Silicate-Soap.*

MIL-C-5410, *Cleaning Compound, Aluminum Surface, Non-Flame Sustaining.*

MIL-C-5543, *Cleaning Compound, Washing Machine for Aircraft Metal Parts.*

P-C-436, *Cleaning Compound, Alkali, Boiling Vat (Soak) or Hydrosteam.*

P-C-437, *Cleaning Compound, High Pressure (Steam) Cleaner.*

P-D-680, *Solvent, Dry Cleaning.*

MIL-D-16791, *Detergents, Nonionic.*

TT-T-291, *Thinner, Paint, Volatile Mineral Spirits (Grade 1).*

MIL-C-4036, *Cleaner, Vapor Pressure, Spray Rinse.*

MIL-D-12491, *Degreaser, Solvent, Tank Immersion.*

MIL-S-851, *Steel Grit, Shot, for Blasting Cleaning and Peening.*

TM 38-230-1, TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I and Vol. II.

P-T-236, *Tetrachloroethylene, Technical Grade.*

TM 9-208-1, *Cleaning of Ordnance Materiel.*

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CHAPTER 6

PRESERVATIVES

6-1 GENERAL

This chapter provides information on selection of preservatives. Included in this chapter are considerations in choosing a preservative and data on preservative types, characteristics, and general uses. Also discussed is the situation where contact-type preservatives are not used but rather a barrier or some other protection such as vapor phase inhibitors or volatile corrosion inhibitors are used.

The type of preservative must be correlated with the barrier used to offset the limitations of each. Closely related, therefore, to the material discussed in this chapter are Methods of Preservation (Chapter 7); Barrier Materials and Cushioning Materials (Chapter 8); and Methods of Humidity Control (Chapter 14).

6-2 PRESERVATION AFTER CLEANING

Protection of items after cleaning is required. When specifying processes for cleaning, requirements should be established to provide for the temporary protection of the item pending preservation and packaging or immediate accomplishment of the subsequent packaging operations.

6-3 CONSIDERATIONS IN CHOOSING A PRESERVATIVE

Because of the nature of the various materials used as preservatives, the packaging engineer must consider factors such as the following before selecting the specific preservative most appropriate to the item:

a. What degree of protection does the item require?

b. Should the item be placed in waterproof or water vaporproof package with a light oil-type preservative?

c. Can the item be protected by a thin-film or compound-type preservative without additional barrier protection?

d. Do any characteristics of the item indicate that no contact preservative should be employed or that one type would be more compatible with the nature of the item than another?

e. Will removal of the preservative prior to use of the item present any special problems?

f. Can a dual-purpose material which functions as both preservative and lubricant be used?

g. After consideration of the six factors above, which preservative material will be most appropriate from the standpoint of the production and least costly after consideration of all pertinent factors? (See Fig. 6-1.)

6-3.1 ITEM CHARACTERISTICS

The item characteristics that must be considered when choosing a preservative are:

a. *Chemical Composition.* The preservative material and the packaged item must be compatible to protect against deterioration and prevent harmful interaction between the item and the preservative.

b. *Vulnerability to Deterioration.* The major types of deterioration and the degree to which the item is vulnerable must be known in order for the preservative to provide adequate protection.

c. *Surface Preparation.* The item must be cleaned and dried before application of the preservative to prevent contaminants from counteracting the effects of the preservative. Other problems associated with the lack of cleanliness or complete drying include nonadherence of the preservative to the item surface and interaction between the contaminant and the preservative.

d. *Characteristics of Item Surface.* When an item consists of different types of material, some of which do not require a preservative, the preservative must protect the critical surfaces and be compatible with the portions of the item not requiring preservative. In addition, the surface of the item may have a close tolerance or high polish, thus requiring a preservative that leaves

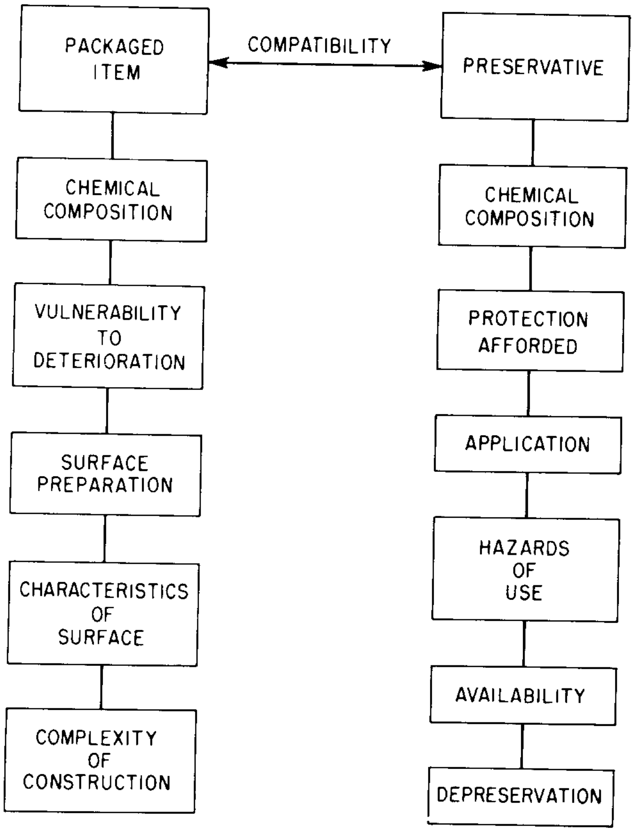

Fig. 6-1. Considerations for Choosing a Preservative

no residue and is nonabrasive. Many preservatives cannot be used if the surface has any crevices or indentions that may be filled during the preservation process and thus require extensive depreservation.

e. *Complexity of Construction.* The preservative must be capable of adequately covering all parts of the items requiring such preservation. Complex items or items with moving parts may require disassembly in order to apply the preservative to all the parts.

6-3.2 PRESERVATIVE CONSIDERATIONS

The preservative characteristics that must be considered when choosing a preservative are:

a. *Chemical Composition.* The preservative and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the preservative.

b. *Protection Afforded.* The protection afforded by the preservative must be commensurate with the major types of deterioration to which the item is vulnerable. If the exact environmental conditions are not known, the preservative must be capable of protecting the item under all normal conditions of shipment and storage.

c. *Application.* The effects of the application process–such as the use of heat, pressure, and moisture–on the item must be determined. Items must not suffer damage to mechanism or structure, or be subject to malfunction or unsafe operating conditions because of the *application or removal* of a preservative compound. Examples of vulnerable items are optical instruments, cameras, and fire control units. Fig. 6-2 illustrates some preservative applications.

d. *Hazards of Use.* The safety of the packaging personnel and subsequent handlers of the item must be considered when a hazard exists if the use of the preservative must take into consideration the availability of proper equipment and trained personnel.

e. *Availability.* The availability of the preservative must be known. If special equipment is required for applying or removing the preservative, it must be available and suitable for use with the item.

f. *Depreservation.* The need for removal of the preservative must be established. Some preservatives do not require removal; thus the item functions normally with the preservative retained on the surface of the item. The effect of the depreservation process on the item also must be determined. Wherever possible, either preservatives that do not have to be removed or those that are easily removed should be used.

6-4 TYPES OF PRESERVATIVES

The principal types of preservatives and their specifications are given in Table 6-1. This table lists Military and Federal Specifications that pertain to preservative materials, the types of materials, characteristics, methods of application and removal, uses, and special considerations.

6-4.1 CONTACT-TYPE PRESERVATIVES

Contact-type preservatives are generally used when the surface of the item is of such a chemical nature that the use of a preservative will provide a protective barrier between the item surface and the environment that surrounds it. These contact preservatives provide effective protection because of their ability to flow over and into all accessible areas of exposed surfaces and because they resist the corroding effect of moisture. These preservatives retard the effects of corrosive elements of the atmosphere until chemical or physical breakdown occurs.

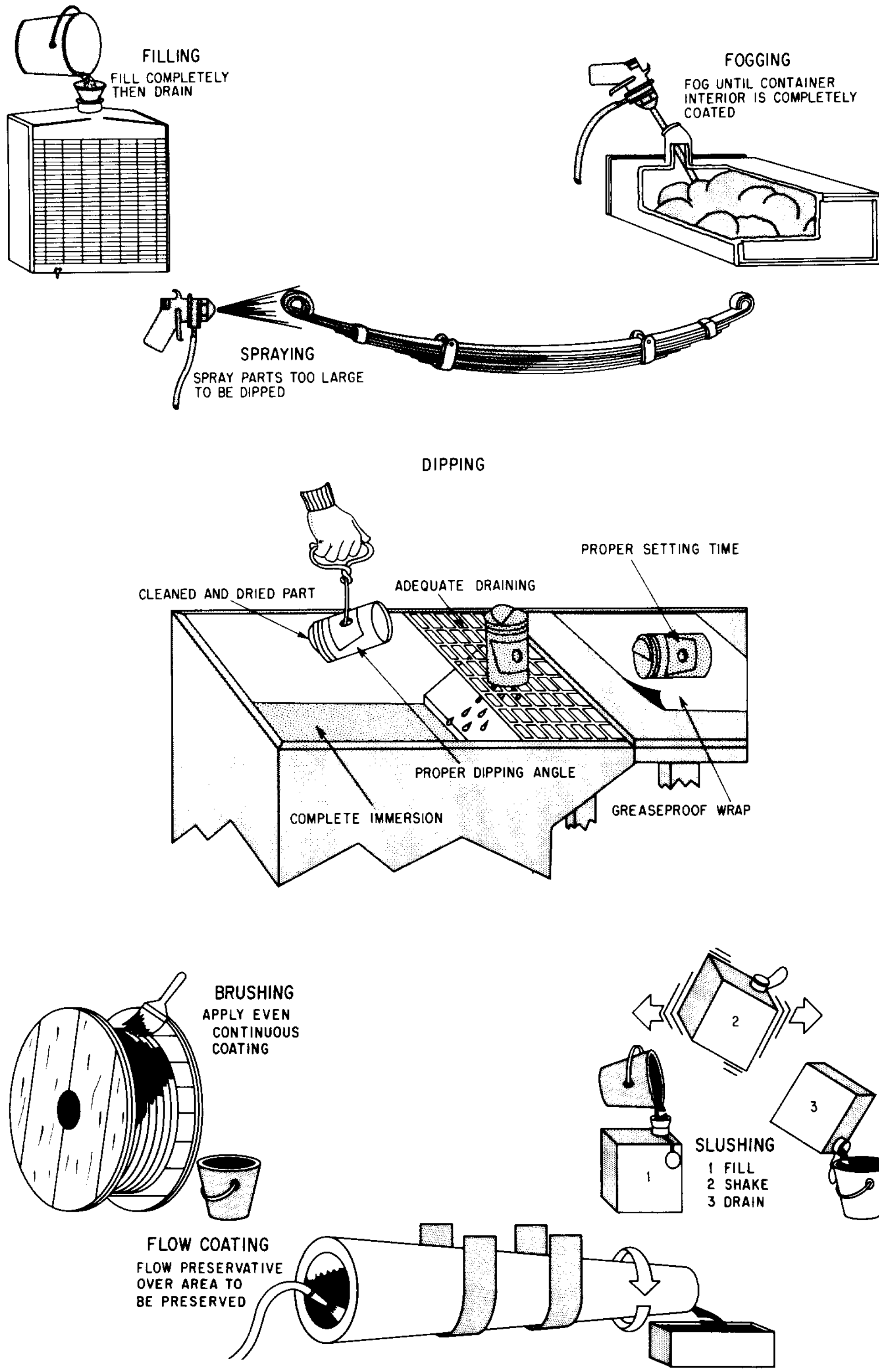

Fig. 6-2. Preservative Applications

TABLE 6-1
TYPES OF PRESERVATIVES

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-C-16173 CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD-APPLICATION	Grade 1 Hard Film (P-1)	175	100			Dipping, spraying or brushing at room temperature.	Not usually required. Can be accomplished by vapor degreasing or with petroleum solvents.	Protection of noncritical metal items that are stored outdoors or where a "dry-to-touch" film is desired. Should not be used on items requiring removal of film for operation. Used on bolts, chains, bale hooks and similar items.
	Grade 2 Soft Film (P-2)		100			Dipping, spraying or brushing at room temperature.	Petroleum Solvents or vapor degreasing.	Extended under cover protection to interior or exterior surfaces of machinery, instruments, bearings or material with or without use of supplementary barrier materials, for outdoor use for limited periods where metal temperature does not prevent film flow.
	Grade 3 Water Displacing. Soft Film (P-3)		100			Dipping, brushing, spraying of exterior; flushing, filling or slushing of interiors at room temperatures.	Vapor degreasing or petroleum solvents.	Used where fresh or salt water must be displaced from corrodible surfaces and the corrosion prevented

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
	(P-3 Contd.)							or stopped; for protecting interior surfaces of machinery; instruments, or material under cover for limited periods and for protecting critical bare steel or phosphated surfaces for extended periods when satisfactorily packaged.
MIL-C-11796 CORROSION PREVENTIVE COMPOUND, PETROLATUM, HOT APPLICATION	Class 3 Thin Soft Grease-like Film (P-6)	130	350	135		Applied either by brushing or swabbing at room temperatures, or by dipping in the molten state at temperatures not to exceed 180 degrees F.	Vapor degreasing or petroleum solvents.	Preservation of antifriction bearings for use on machined surfaces for which a protective material that is brushable and easily removable at room temperature is required.
MIL-L-3150 LUBRICATING OIL, PRESERVATIVE, MEDIUM	One Grade only, Viscosity same as SAE 30 (P-7)				20	Applied at room temperature by any applicable method except fogging.	Vapor degreasing or petroleum solvents.	For lubricating and preserving internal surfaces of machine assemblies (other than internal combustion engines), for artillery and small arms, transmissions, differ-

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
								entials and fuel tanks. Used as a temporary preservative on items and equipment awaiting processing for long term storage and for maintaining supplies and equipment in the reserve fleet.
VV-L-800 LUBRICATING OIL, GENERAL PURPOSE, PRESERVATIVE, (Water Displacing Low Temperature).	One Grade only. (P-9)		275 Min.	NOTE: The oil loses its newtonian properties at very low temperatures; its use at temperatures below -40°F is limited by a number of machine design factors and should be proved for any specific item application by test before adoption.	-70 or lower.	Any method at room temperature.	Petroleum Solvents or vapor degreasing	For use in lubrication and protection against corrosion of certain small arms, automatic weapons, fuze mechanisms, components of internal combustion engines and wherever a general purpose low temperature lubricating oil is required.
MIL-L-21260 LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, PRESERVATIVE AND BREAK-IN	Type I & Type II (P-10) Grade 10 Grade 30		 360 390		 -20 0	Any method at room temperature.	Petroleum Solvents. Removal before use is generally not required.	Type I. For lubrication of spark ignition type of reciprocating in-

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-L-21260 (Contd.)	Grade 50 (Type I only) (P-10)		400	15				ternal combustion engines, operating below 150 p.s.i., BMEP, for preservation, use, for engine break-in and for operation until the first scheduled oil change. Type II. Same usage as Type I, except for supercharged compression-ignition engines operating at approximately 150 p.s.i. BMEP, and above.
MIL-C-6529 CORROSION PREVENTIVE, AIRCRAFT ENGINE. (For Aeronautical Applications See P-10 MIL-C-8188 below)	Type I Concentrated Material (P-10)		400		10	Brush, dip, spray, flow-coating, slushing, filling, or flushing and fogging.	Petroleum solvents vapor degreasing (Removal not usually required).	Corrosion preventive for piston engines when used in MIL-L-6082 oil and for jet engines when used in MIL-O-6081 oil.
	Type II Ready Mixed for Reciprocating Aircraft engines.		400		10			Corrosion-preventive lubricant for reciprocating aircraft engines.
	Type III Ready		400		10			Corrosion-preventive lubricant for

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-C-6529 (Contd.)	Mixed for Turbo-jet Aircraft engines							jet aircraft engines which require use of MIL-0-6081 oil.
MIL-C-8188 CORROSION-PREVENTIVE OIL, GAS TURBINE ENGINE, AIRCRAFT, SYNTHETIC BASE (For Processing Army Helicopter Engines).	Grade A High temperature oil Grade B Low temperature oil.		400		-75	Filling.	Draining.	For preservation of turbo-prop and turbo-jet engines using MIL-L-7808 oils. Use should not exceed 20 hours as an aircraft engine lubricant. Will be used for both preservation and final acceptance runs of aircraft engines requiring the use of specification MIL-L-7808 oils.
MIL-G-23827 GREASE, AIRCRAFT AND INSTRUMENT, GEAR AND ACTUATOR SCREW. (For Aeronautical Applications)	One Grade only. (P-11)					Brush, swab or grease gun at room temperature.	Toluene, benzene or hot SAE oil followed by solvent. Removal not generally required.	For ball, roller and needle bearings and gears; and on sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear and aircraft control systems, during high and low temperature operations.

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-G-10924 GREASE, AUTOMO-TIVE AND ARTILLERY.	One Grade Only (P-11)					Brush, grease gun or swabbing at room temperature.	Toluene, benzene or hot oil follow-ed by agitated petroleum solvent rinse (removal not usually required).	For lubrication of automotive and ar-tillery equipment operating tempera-ture range of minus 65°F to plus 175°F.
MIL-G-7711 GREASE, AIR-CRAFT GENERAL PURPOSE (For Navy Ordinance Application.)	One Grade Only (P-11)							General purpose aircraft grease is intended for use in anti-friction bear-ings, gear boxes, and plain bearings where operation at both low tempera-ture (-40°F) and high temperature (250°F) may be required.
MIL-C-10382 CORROSION, PREVENTIVE, PETROLEUM, SPRAYING APPLI-CATION, FOR FOOD HANDLING MACHINERY AND EQUIPMENT.	One Grade Only (P-14)		100 min.	150 min.		Spraying at room temperature.	Hot water or pe-troleum solvents.	For use on food handling machinery and equipment. The residual material after evaporation shall be harmless if inadvertently ingested by per-sonnel.

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-L-6085 LUBRICATING OIL, INSTRUMENT, AIRCRAFT, LOW VOLATILITY	One Grade Only. (P-17)		365		-70	Applied by dipping, spraying or squirt oiler.	Removal not required. But, if necessary, solvent rinse should be sufficient.	For use in aircraft instruments, electronic equipment, or where a low evaporation oil is required for both high and low temperature application, and where oxidation and corrosion resistance are desired.
MIL-P-3420 PACKAGING MATERIALS, VOLATILE CORROSION INHIBITOR, TREATED OPAQUE	Type 1 (P-18)					Surface covered with a carrier, (with a volatile corrosion inhibitor) at room temperature in accordance with MIL-I-8574.	Any safe method at room temperature.	Type I. For general protection against corrosion of ferrous, aluminum, aluminum base alloys. Also, zinc plate, cadmium, lead-base alloys and zinc-base alloys. See MIL-I-8574.
	Type II							Type II. Shall not be used where equipment and parts include non-metallic components and where plastic barrier materials are involved.

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-P-16173 CORROSION PREVENTIVE COMPOUND SOLVENT, CUT-BACK, COLD-APPLICATION.	Grade 4 Transparent Non-Tacky Film (P-19)	175	100					General purpose indoor and limited outdoor preservation or corrodible metals with or without an overwrap where tack-free and transparent coating is required; non-miscible with lubricating oil.
MIL-I-23310 INHIBITORS, CORROSION, VOLATILE, OIL TYPE (For Navy Use.)	Grade 1 Low Viscosity Oil. (P-19 Contd.) Grade 2 Medium Viscosity Oil. (P-20)		300 300		-20 0	Fogging.	Removal from combustion chamber not required.	Use as a preservative in "closed" systems constructed essentially of ferrous alloys, with components containing aluminum and aluminum base alloys.
MIL-L-46002 LUBRICATING OIL, CONTACT AND VOLATILE CORROSION INHIBITED	Grade 1 Light Viscosity Oil. (P-20 Contd.)		240		-50	Filling. Note: This oil is not effective unless an adequate reservoir of oil can be maintained. A minimum of 0.15 quart for Grade 1 and 0.25 quart for Grade 2 should be		Use in the preservation of inclosed systems where the volatile components will provide protection above the oil level. May also be effectively utilized as a con-

TABLE 6-1
TYPES OF PRESERVATIVES (Cont.)

Specification No.	Type and P-No.	Flow Point, °F	Flash Point, °F	Melting Point, °F	Pour Point, °F	Method and Temperature of Application	Method of Removal	Uses
MIL-L-46002 (Contd.)	Grade 2 Medium Viscosity, oil, (P-20 Cont'd)		250		-10	utilized for each cubic foot or area to be protected.		tact preservative. Is not intended for use as an operational preservative oil and should not be used in applications where magnesium, cadmium plated, or rubber components are present.

NOTE: Hydraulic preservative oils have not been listed because of variations in system requirements. Hydraulic preservatives used shall be subjected to approval by the procuring agency.

Contact preservatives are four basic types:

(1) Thin-film, solvent cutback, cold application

(2) Petroleum base, hot application

(3) Oils, rust inhibited, cold application

(4) Special purpose, cold application.

All of these preservative materials have their peculiar characteristics and are capable of protecting for varying periods of time and under a wide range of severity of exposure conditions.

6-4.2 VOLATILE CORROSION INHIBITORS (VCI)

During World War II, materials described as vapor phase inhibitors were developed to protect ferrous alloys during storage and shipment. These were a class of substituted ammonium nitrites, with a significant but controlled vapor pressure, whose vapors possess definite corrosion inhibitive characteristics. Such materials are stable chemical salts usually formed from a volatile acid and a volatile base. The resulting vapor pressure may vary considerably between salts, but it is ordinarily low in order to assure reasonable persistence in a nonhermetic closure. The mechanism of the vaporization of the salt appears to involve its hydrolysis in the presence of moisture and an equilibrium recombination within and on surfaces in the enclosure. In general, good chemical stability appears to depend on a reasonable balance of volatility between the acid and base involved; certain amine nitrites are particularly effective.

VCI protection is equal to, or better than, that provided by the more commonly used P-type preservative compounds. VCI provides good protection to areas of an item where it would be impossible or impractical to apply a grease- or oil-type preservative. This material has been successfully used in the prevention of ferrous parts of assemblies under controlled conditions of application. VCI packaging materials have also been used for the preservation of parts or assemblies containing cadium, lead, zinc, or magnesium of less than 15 percent alloying content.

Oil with VCI is available for use as a preservative in enclosed systems where the VCI will provide protection above the oil level. MIL-L-46002 covers one such application. VCI oil can also be effectively used as a contact preservative. It should not be used in application where magnesium, cadmium-plated, or rubber components are present.

Information on the use of volatile corrosion inhibitors is not yet complete enough to permit general uncontrolled use of this material, although the successful use of the material eliminates the need for difficult and expensive depreservation when putting the item in use. Volatile corrosion inhibitors, which should be applied only to specific items, are subject to the limitations of MIL-I-8574 (Ref. 1). VCI treated materials should conform to MIL-P-3420.

Care must be taken in relation to assemblies which may contain plastics, painted parts, or components of natural or synthetic rubber. Assemblies should not be packaged with VCI if any of the parts are made of these materials until proof is established that they have passed the compatibility test required by MIL-I-8574.

In addition to the previously stated limitations, VCI method should not be used on the following general types of items until the protection problems have been resolved:

a. Items made of, or containing, a substantial percentage of copper

b. Optical items, unless specifically authorized by service or bureau concerned

c. Categories of items not specifically approved by service or bureau concerned.

VCI materials are supplied in the form of coated and impregnated wrapping papers, barrier materials, fiberboard laminates, flexible transparent films, crystalline solids, fabricated bags, treated lubricating oils, and other forms. Space does not permit a complete listing of these forms for which specifications have been developed. More detailed information concerning VCI can be found in applicable publications (Ref. 2).

REFERENCES

1. MIL-I-8574, *Inhibitors, Corrosion, Volatile, Utilization of.*
2. TM 38-230-1, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I.
3. AMCP 706-123, Engineering Design Handbook, *Hydraulic Fluids.*

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MIL-C-16173, *Corrosion Preventive Compound, Solvent Cutback, Cold Application.*

MIL-C-11796, *Corrosion Preventive Compound, Petrolatum, Hot Application.*

MIL-L-3150, *Lubricating Oil, Preservative, Medium.*

MIL-L-3503, *Lubricating Oil, Preservative, Light.*

VV-L-800, *Lubricating Oil, General Purpose, Preservative (Water-Displacing, Low Temperature).*

MIL-L-21260, *Lubricating Oil, Internal Combustion Engine, Preservative, Light Viscocity.*

MIL-C-6529, *Corrosion Preventive, Aircraft Engine.*

MIL-C-8188, *Corrosion Preventive Oil, Gas Turbine Engine, Aircraft, Synthetic Base.*

MIL-G-23827, *Grease, Aircraft and Instrument, Gear and Actuator Screw.*

MIL-G-10924, *Grease, Automotive and Artillery.*

MIL-G-81322, *Grease, Aircraft, General Purpose Wide Temperature Range.*

MIL-C-10382, *Corrosion Preventive Petrolatum, Spraying Application; for Food Handling Machinery and Equipment.*

MIL-L-6085, *Lubricating Oil; Aircraft Instrument, Low Volatility.*

MIL-P-3420, *Packaging Materials, Volatile Corrosion Inhibitor, Treated, Opaque.*

MIL-P-116, *Preservation, Methods of.*

CHAPTER 7

METHODS OF PRESERVATION

7-1 PACKAGING AND PRESERVATION

Methods of preservation for military packaging as specified in MIL-P-116 (Ref. 1) are used as a convenient form for describing the various combinations of packaging operations involved prior to insertion of packaged items into their shipping or intermediate containers. These operations include cleaning and drying (Chapter 5), preservative selection and application (Chapter 6), selection of greaseproof and cushioning wraps and barriers (Chapter 8), and selection of containers (Chapter 9).

The basic methods of preservation (Fig. 7-1 and Table 7-1) prescribed in MIL-P-116 are:

a. Method I: Preservative coating (with greaseproof wrap as required)

b. Method IA: Water-vaporproof enclosure (with preservative as required)

c. Method IB: Strippable compound coating (hot dip)

d. Method IC: Waterproof barrier (with preservative as required)

e. Method II: Water-vaporproof barrier with desiccant (with contact preservative when required)

f. Method III: Packaging for mechanical and physical protection only.

7-2 SUBMETHODS

Basically, all submethods within a specific method are equal in at least one important characteristic. However, the submethods within a basic method are not equal in other important respects. Differences between submethods exist in characteristics such as strength of barriers, physical protection afforded both item and package, labor and material costs involved, cube and weight of resulting package, and storage and transportation costs.

The methods of preservation specified in MIL-P-116 are, for all practical purposes, considered mandatory when applicable. Deviations from these methods are justified only when the nature of the item to be packaged precludes their use or when the type of storage to be used makes them unnecessary.

7-3 ADHERENCE AND UNIFORMITY OF METHODS

Adherence to these prescribed methods of preservation is extremely important since requirements established during the package-engineering phase of package development are usually applicable throughout the supply system. Consequently, the manner in which an item is to be preserved and packaged at the time of procurement must be recognizable as to methods and materials by any recipient in the supply system. The use of unknown methods and materials could result in repackaging within the supply system if there were any question as to the adequacy of the methods and materials used.

Equally important is the requirement for uniformity of methods and materials whether an item is packaged by a manufacturer or at an Army depot. This necessitates the use of only those packaging materials which are available within the supply system. Strict adherence, whenever possible, to the methods and materials specified in MIL-P-116 will accomplish this.

7-4 METHOD DETERMINATION

Selection of the proper method of preservation is one of the most important decisions that a packaging engineer must make. The primary consideration in making this decision is the degree of physical and environmental protection required, which depends upon the susceptibility of the item to damage from the physical and chemical environment the package will experience until the item is used.

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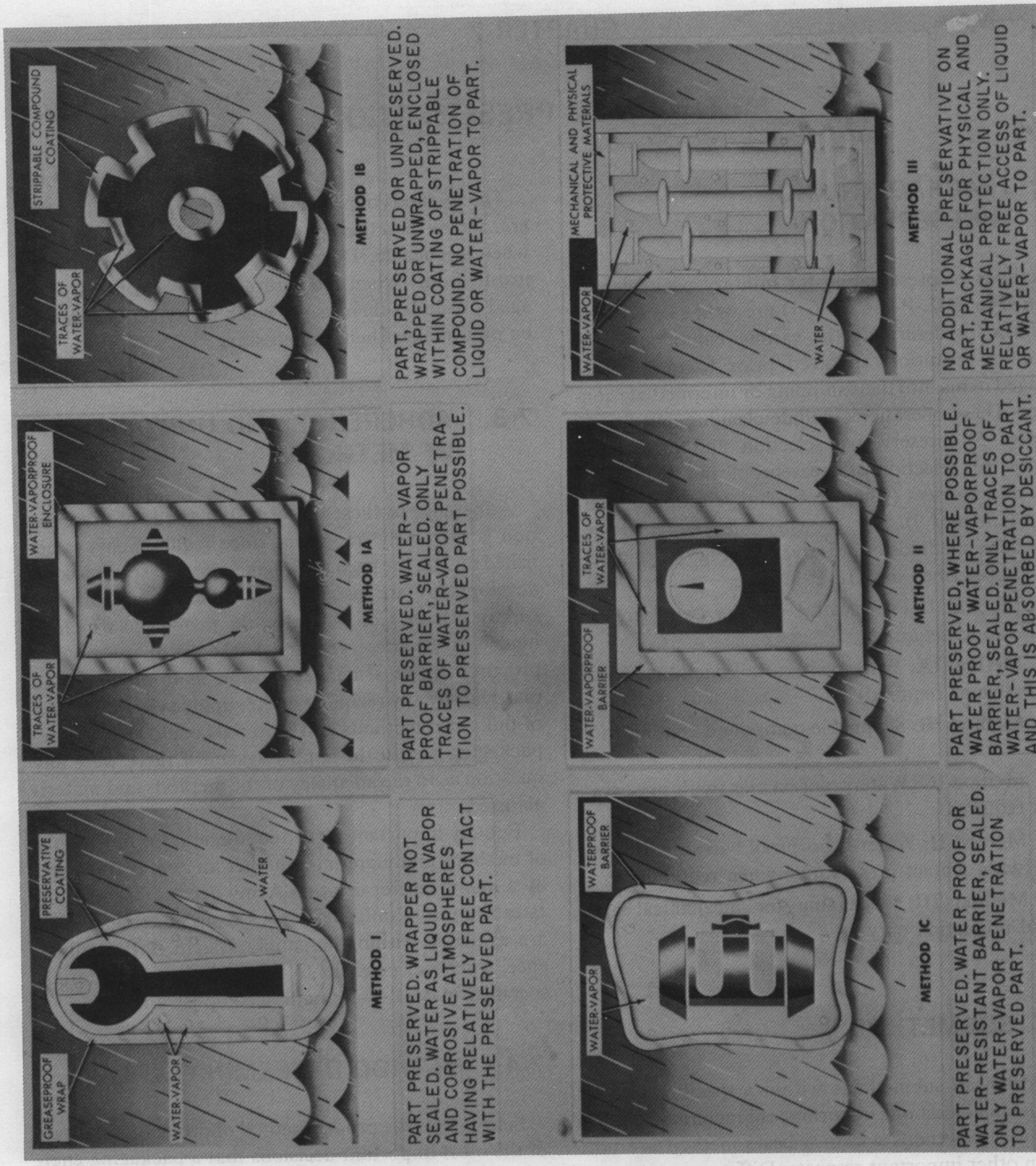


Fig. 7-1. Methods of Preservation

TABLE 7-1
SUMMARY OF MIL-P-116*

PRESERVATION METHODS			
Method I:	Preservative Coating (with greaseproof wrap as required)	IC-7:	Blister Package Multiple Compartment, Individually Sealed
Method IA:	Water-Vaporproof Enclosure (with preservative as required)	IC-8:	Skin Package Vacuum Formed
IA-5:	Rigid Metal Container, Sealed	Method II:	Water-Vaporproof Barrier With Desiccant (with contact preservative when required)
IA-6:	Rigid Container, (items immersed in preservative, oil type) Sealed	Method IIa:	Floating Bag
IA-8:	Water-Vaporproof Bag, Sealed	Method IIb:	Container, Barrier, Container
IA-13:	Rigid Container Other Than All Metal, Sealed	Method IIc:	Cushioned Item Bag
IA-14:	Container, Bag, Container	Method IId:	Rigid Metal Container, Sealed
IA-15:	Container, Bag	Method IIe:	Container, Barrier
IA-16:	Floating Barrier	Method IIf:	Rigid Container, Other Than All Metal Sealed
Method IB:	Strippable Compound Coating (hot dip)	Method III:	Packaged for Mechanical and Physical Protection Only
IB-1:	Direct Application of Strippable Compound		
IB-2:	Aluminum Foil Wrap, Strippable Compound		
Method IC:	Waterproof Barrier (with preservative as required)		
IC-1:	Greaseproof, Waterproof Bag, Sealed		
IC-2:	Container, Overwrapped With Waterproof Carrier Material, Sealed		
IC-3:	Waterproof Bag, Sealed		
IC-4:	Waterproof Fibre Can With Metal Ends, Sealed		

*This Chart covers MIL-P-116E, Amend 2, 1 Nov. 1966.

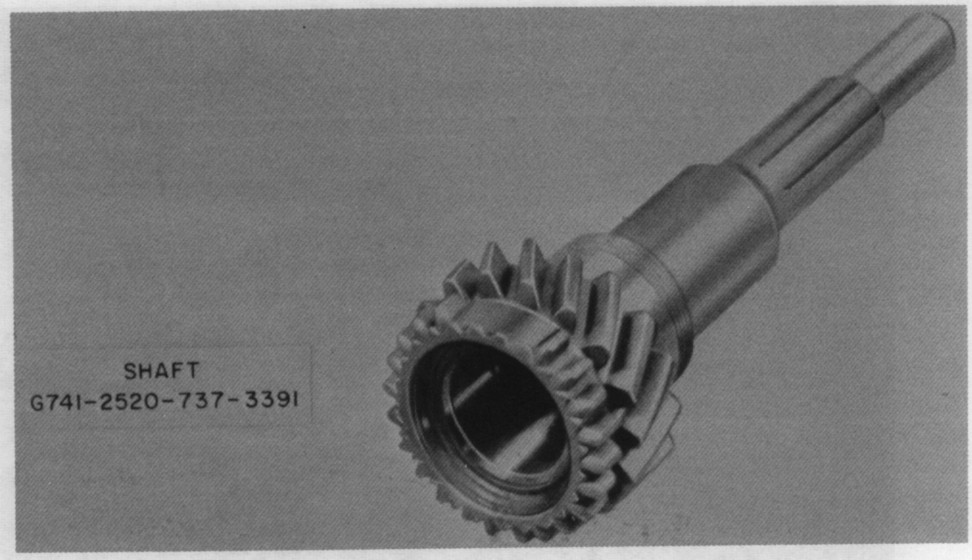
TABLE 7-1
SUMMARY OF MIL-P-116* (Cont.)

CLEANING METHODS**	DRYING METHODS	PRESERVATIVES
C-1: Any Applicable Process	D-1: Prepared Compressed Air	P-1: Thin Film Preservative (hard drying, cold application)
C-3: Petroleum Solvent Cleaning	D-2: Oven	P-2: Thin Film Preservative (soft film, cold application)
C-5: (Process C-3 followed by process C-8)	D-3: Infrared Lamps	P-3: Thin Film Preservative, Water Displacing (soft film, cold application)
C-7: Vapor Degreasing	D-4: Wiping	P-6: Light Preservative Compound (Soft film)
C-8: Perspiration and Fingerprint Removal	D-5: Draining	P-7: Medium Preservative Oil (cold application)
C-9: Alkaline Cleaning		P-9: Very Light Preservative Oil (cold application)
C-11: Electrocleaning		P-10: Engine Preservative Oil
C-14: Steam Cleaning		P-11: Preservative Grease (application as required)
C-15: Abrasive Blast		P-14: Corrosion Preventive (food handling machinery and equipment nontoxic)
C-16: Abrasive Blast (Honing Process)		P-15: Hydraulic Preservative Oil
C-17: Soft Grit Blast		P-17: Instrument Bearing Preservative Oil
C-18: (Process C-7 followed by process C-8)		P-18: Volatile Corrosion Inhibitor
		P-19: Thin Film Preservative (transparent, non-tacky)
		P-20: Lubricating Oil, Contact and Volatile Corrosion Inhibitor Treated

* This chart covers MIL-P-116E, Amend. 2, 1 Nov. 1966

** Cleaning processes are explained in Table 5-2.

NOTE: Methods listed are subject to change. See latest revision of MIL-P-116 before selecting a method.



PACKAGING COSTS

Method	Qty-per Intermediate Pack	Qty-per Exterior Container	Weight of Exterior Container, lb	Cube of Exterior Container, ft3	Labor Packaging Cost per Unit, $	Material Packaging Cost per Unit, $	Total Packaging Cost per Unit, $
IA-13	4	32	156	3.47	0.43	0.26	0.69
IB-2	4	32	140	2.15	0.98	0.15	1.13
IA-14	4	32	172	4.175	0.78	0.51	1.29

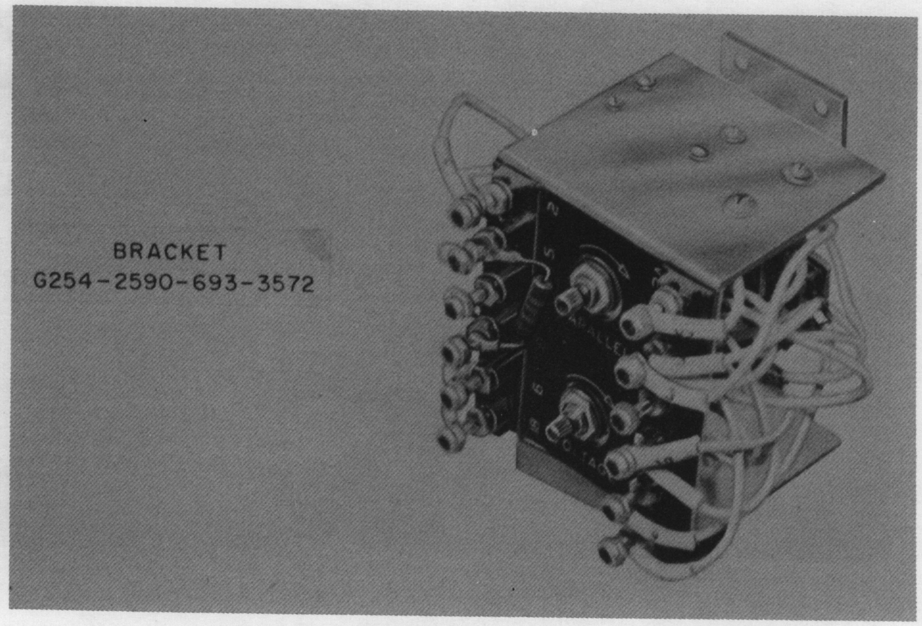
SHIPPING AND STORAGE COSTS

Method	Intermediate Weight, lb	Intermediate Cube, ft3	Weight per 10,000 Intermediate Containers, lb	Cube per 10,000 Intermediate Containers, ft3	Pkg. Cost per 10,000 Intermediate Containers, $
IA-13	19.5	0.4345	195,000	4345	27,600
IB-2	20.25	0.4722	202,500	4722	45,200
IA-14	21.5	0.5218	215,000	5218	51,600

Storage at $0.217 per Cubic Foot	Transportation RRA to New York	Export East Coast at $35.00 per Ship Ton	Total Cost of Method
$942.86	$5382	$3801.87	$37,726.73
1024.67	5589	4131 75	55,945.42
1132.30	5934	4565.75	63,232.05

Note: Costs shown are for comparison purposes only.

Fig. 7-2. Cost Analysis for Determining Method of Packaging for Shaft



PACKAGING COSTS

Method	Qty-per Intermediate Pack	Qty-per Exterior Container	Weight of Exterior Container (lb)	Cube of Exterior Container (ft3)	Labor Packaging Cost per Unit ($)	Material Packaging Cost per Unit ($)	Total Packaging Cost per Unit ($)
II-f	4	48	167	6.44	0.34	0.48	0.82
IA-15	4	48	131	5.53	0.53	0.36	0.89
IA-5	4	48	190	8.08	0.82	1.11	1.93
II-d	4	48	199	8.08	0.89	1.17	2.06

SHIPPING AND STORAGE COSTS

Method	Intermediate Weight (lb)	Intermediate Cube (ft3)	Weight per 10,000 Intermediate Containers (lb)	Cube per 10,000 Intermediate Containers (ft3)	Pkg. Cost per 10,000 Intermediate Containers ($)
II-f	13.5	0.584	135,000	5840	32,800
IA-15	10.92	0.461	109,160	4610	33,320
IA-5	15.83	0.673	158,330	6730	77,240
II-d	16.58	0.673	165,800	6730	82,400

Storage at 0.217 per Cubic Foot	Transportation RRA to New York	Export East Coast at $35.00 per Ship Ton	Total Cost of Method
$1276.28	$3726.00	$5110.00	$42,912.28
1000.37	3012.81	4033.75	41,366.93
1460.41	4369.91	5888.75	88,959.07
1460.41	4576.08	5888.75	94,325.24

Note: Costs shown are for comparison purposes only.

Fig. 7-3. Cost Analysis for Determining Method of Packaging for Electronic Bracket

Once the required degree of protection has been established, further analysis is required to determine the specific submethod and combination of packaging materials to be used. This analysis takes into consideration, as a minimum, the following factors:

a. Labor costs

b. Materials costs

c. Transportation costs (relative to cube and weight)

d. Storage space and cost.

Only when all of these factors are considered can the packaging engineer be sure that he has selected a method and materials that not only provide the required degree of protection, but provide it at minimum overall cost. Actual analyses of this type are shown in Figs. 7-2 and 7-3. In both cases it was first determined which of the methods specified in MIL-P-116 would adequately protect the item. All of the various factors affecting the total costs for each of the methods were then determined and assembled for comparison purposes.

It is to be noted from these examples that if only some of the pertinent factors are considered, erroneous conclusions could be drawn regarding the comparative costs of the methods. All factors affecting cost must be considered in the analysis if the results are not to be suspect.

REFERENCE

1. MIL-P-116, *Preservation, Methods of.*

BIBLIOGRAPHY

TM 38-230-1, TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I and Vol. II.

NAVORD Report 6510, Vol. I and Vol. II, *Report on the Proper Method of Selecting and Specifying Preservation, Packaging, and Packing,* Bureau of Ordance, Department of the Navy, October 1958.

CHAPTER 8

BARRIER MATERIALS AND CUSHIONING MATERIALS

This chapter provides data to aid the packaging engineer in the selection of barrier and cushioning materials. As discussed in Chapter 7, all packaging materials must be selected in accordance with the method of preservation prescribed.

8-1 BARRIERS

The design of packages intended to conform to specification MIL-P-116 considers, in the majority of cases, the use of one or more barriers. All IA, IB, IC, and Method II submethods incorporate some type of a barrier between the item and the atmosphere.

8-1.1 TYPES AND PURPOSES

The properties of the principal types of barriers are given in Table 8-1. Included are dual purpose materials that also serve as cushioning. Table 8-2 gives properties of packaging films, while Table 8-3 relates the wrapping and marking characteristics of packaging films.

Barriers fall into the following four general classifications:

(1) *Greaseproof.* These barriers are used when the item being packaged has been treated with a transferable grease, oil, or compound. Greaseproof barriers may be wraps or, where economy and adequacy dictate, envelopes or bags. To retain the preservative in intimate contact with the item and prevent other components of the package from absorbing the preservative, these barriers are interposed between the preservative-coated item and the package.

(2) *Neutral and Cushioning Wraps.* Although these materials are not true barriers they are many times treated as such. Used as a barrier, they are employed to prevent surfaces of packaged items from coming into contact with elements of the package which by their chemical nature could cause corrosion. Where no grease- or water-proofness is required, these wraps are the most economical.

(3) *Waterproof and Greaseproof Barriers.* These are used when waterproofness is a requirement and when the nature of the item being packaged is not critical enough to require a moisture-vaporproof barrier. Barriers in this group, which may range from plastic-coated Kraft papers to semi-rigid metal and fiber cans, are usually used in packages conforming to Method IC of MIL-P-116.

(4) *Greaseproof, Waterproof, Moisture-vaporproof Barriers.* These are used when maximum protection of the item is required (Methods IA and Method II packages). Included in this group are plastic-foil-scrim-plastic, plastic-foil-Kraft-paper, metal-end-fiber cans, and rigid metal containers. Greaseproof barriers are selected for preservative retention as their principal function. Waterproof barriers are used for a variety of items; paper gaskets, metallic components having finishes and surface treatments rendering them comparatively immune to corrosion, or where a moderate amount of corrosion can be tolerated. Moisture-vaporproof barriers are used where the lighter preservatives must be used on highly finished surfaces and also where, because of the nature of the items, no preservative can be used. In such cases, the ultimate package is usually desiccated to attain and maintain a low enough relative humidity to prevent any corrosion that would affect the use of the item. (See Chapter 14.)

8-1.2 SELECTION

Although many considerations must be applied in the selection of a proper barrier, the following factors usually apply:

a. The barrier must provide neutrality, grease-, water-, or watervapor-proofness indicated by the submethod of packaging being designed.

b. The type, grade, class, and amount of the barrier selected must be of sufficient strength and quantity to protect the item.

c. After determination of the barrier, strength, and any cushioning factor used, the most economical material having the desired qualities shall be selected. (See Fig. 8-1.)

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[1-9]

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
MIL-B-121 BARRIER MATERIAL, GREASEPROOFED, WATERPROOFED, FLEXIBLE	Type I - Heavy duty					Flexible, greaseproof, waterproof barrier material for the protection of military supplies and equipment during transportation and storage under all climatic conditions. Grade A, Class 1 material is primarily used to fabricate greaseproof, waterproof bags. It may also be used as intimate wrap. Grade A Class 2 material is used as intimate wrap to protect preservatives, and to insulate metal surfaces from hygroscopic materials, Grade C material is primarily used as an outer wrap and sealed by wax dip, used as intimate wrap only for critical items with soft preservatives.
	Grade A- Greaseproofed, waterproofed and noncorrosive.					
	Class 1 -- Heat sealable, nonstretchable.	45	150	30		
	Class 2 -- Nonheat sealable, stretchable.	45	150	25		
	Grade C- Greaseproofed, waterproofed, noncorrosive, moldable and self-adhering					
	Class 1 -- Self adhering coating applied on nongreaseproof side only	45	500	20		
	Class 2 -- Self adhering coating applied on both sides	45	500	20		

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
MIL-B-121 (Continued)	Type II - Medium duty					
	Grade A- greaseproofed, waterproofed, and noncorrosive.					
	Class 1-- Heat sealable, non stretchable.	30	100	20		
	Class 2-- Non heat sealable, stretchable.	30	100	18		
MIL-P-130 PAPER, WRAPPING, LAMINATED	Type I-Heavy duty-	40	250	40		Protective cover or wrapper over greaseproof wrappers. Added protection against mechanical damage.
	Type II-Medium duty-	35	200	30		
	Type III-Light duty-	30	150	20		
MIL-B-131 BARRIER MATERIAL, WATER VAPORPROOF, FLEXIBLE, HEAT SEALABLE	Class 1 -- General use			50	Good resistance to delamination.	Where heat sealable, flexible barrier is required. Water vaporproof.
	Class 2 -- Limited use			25	Good resistance to delamination.	For use where weight inside barrier does not exceed 10 pounds with combined dimension not to exceed 42 inches. Not to be used in floating bag applications, packaging below 32°F where manipula-

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specifications	Type	Characteristics				General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)	Other	
MIL-B-131 (Continued)						tion is required, or where double seam junctions are required.
MIL-A-148 ALUMINUM FOIL	Type I-Rolls Type II-Interfolded flat sheets Class 1 -- Flat sheets, 12" x 10 3/4" Class 2 -- Flat sheets, 9" x 10 3/4" Type III-Single-ply Flat sheets					Grade A-for food handling and processing applications. Grade B for application other than food handling or processing. Used in place of Grade A (MIL-B-121) only after approval of processing agency of a noncorrosive barrier between preserved surface and surface that may cause corrosion. Direct contact with metals other than cadmium, magnesium, or zinc should be avoided where water is present to prevent electrolytic action
MIL-B-13239 BARRIER MATERIAL, WATERPROOFED, FLEXIBLE ALL TEMPERATURES	Type B-1-Bailing case liners and wrappers, two-way stretchable	45 (dry) 15 (wet)	200 (dry)	25 (dry) 10 (wet)		For the protection of military supplies during handling, storage, transit, and service in all climatic conditions.

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
MIL-B-13239 (Continued)	Type B-2-1/- Interior wrappings and material for interior packaging bags. 1/-Stretchable can be specified	See grades below	See grades below	See grades below		Do not use Type B-1 in direct contact with bare metal.
	Type B-3-Material for interior packaging bags, stretchable	30 (dry)	100 (dry)	20 (dry)		For further usage see 6.1 of basic specification.
	CW-1 Case liners and wrappers, stretchable	45 (dry) 15 (wet)	250 (dry)	30 (dry) 10 (wet)		
	CW-2 Case liners and wrappers, non stretchable	45 (dry) 15 (wet)	200 (dry)	30 (dry) 10 (wet)		
	CLASSES					
	1-Heat sealable					
	2-Nonheat sealable					
	GRADES (Type B-2 only)					
	A-Heavy duty	45 (dry) 10 (wet)	150 (dry)	30 (dry) 8 (wet)		
	B-Medium duty	30 (dry) 8 (wet)	100 (dry)	20 (dry) 5 (wet)		
	C-Light duty	25 (dry) 6 (wet)	75 (dry)	10 (dry) 3 (wet)		

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
MIL-P-17667 PAPER, WRAPPING, CHEMICALLY NEUTRAL (NON CORROSIVE)	Type I Flat (Basic weight 500 sheets 24x36 inch)				Water resistance (Dry Indicator)	Initial wrap of items requiring a noncorrosive, dust protective wrap applied prior to or as part of unit packaging where a greaseproof wrap is not needed.
	15 lb	10	15	5	3 sec	
	30 lb	21	45	10	15 sec	
	55 lb	39	100	20	40 sec	
	80 lb	56	160	35	50 sec	
	Type II Creped					
	Class 1 -- Creped in 1 direction					
	35 lb	14	90	8	15 sec	
	50 lb	20	130	10	25 sec	
	70 lb	27	160	18	40 sec	
	Class 2 -- Creped in 2 directions					
	20 lb	14	40	3	5 sec	
	40 lb	22	90	6	25 sec	
	73 lb	30	150	11	40 sec	
MIL-F-22019 FILM, TRANSPARENT, FLEXIBLE. HEAT SEALABLE. VOLATILE CORROSION INHIBITOR TREATED	One type only	60 psi	20 (Elmendorf)			For use in short term storage of items where transparency is desired to facilitate inspection.

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
MIL-F-22191 FILMS, TRANSPARENT, FLEXIBLE, HEAT SEAL-ABLE, FOR PACKAGING APPLICATIONS	Type I - Water vapor-proof, waterproof, greaseproof				WVTR:0.05 gm/100 sq in/ 24 hr, max.	For use in applications where watervapor impermeability is required.
	Type II - Waterproof, greaseproof				WVTR:0.05 gm/100 sq in/ 24 hr, max.	For use in applications where greaseproofness and waterproofness are required.
	Type III - Waterproof				WVTR: 0.05 gm/100 sq in/ 24 hr. max	For use in applications where protection against water or solid contamination is required.
NNN-P-40 PAPER, LENS	Type I - Lightweight 5.5 lb/24"x36"-- 500 sheets	30 (10 sheets)			pH 5.0 to 7.5	Cleaning and protecting lenses and other glass and highly polished surfaces.
	Type II - Heavyweight 8.5 lb/24"x36"-- 500 sheets			450 gm/15-mm width	pH 5.0 to 7.5	Do not use Type III on precision coated optics or optical plastics.
	Type III - Heavyweight silicone treated 11.8 lb/24"x36"-- 500 sheets	40 (10 sheets)			pH 5.0 to 7.5	

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
NNN-P-40 (Continued)	Type IV - Heavyweight, wet strength-- 10.4 lb/24"x36"-- 500 sheets			1800 gm/15 mm (dry, length) 600 gm/15-mm (dry, width) 450 gm/15-mm (wet, length)	pH 5.0 to 7.5	
	Type V - Lightweight, wet strength-- 7.0 lb/24"x36"-- 500 sheets			700 gm/15-mm (dry, length) 100 gm/15-mm (dry, width) 150 gm/15-mm (wet, length)	pH 4.5 to 7.5	
UU-P-268 PAPER, KRAFT, UNTREATED, WRAPPING (24" x 36" - 500)	Grade A: No. 1 kraft paper					Used where a chemically neutral or greaseproof and waterproof barrier is not required.
	35 lb--	32	85			
	60 lb--	54	150			
	80 lb--	72	210			
	Grade B: No. 2 kraft paper					
	30 lb--	21	50			
	40 lb--	28	75			
	50 lb--	35	100			
	60 lb--	42	130			
	70 lb--	49	160			
	80 lb--	56	190			

TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specification	Type	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
L-P-378 PLASTIC SHEET AND STRIP (POLYOLEFIN)	Type I - Normal impact strength polyethylene			1700 psi	WVTR:10gm/ 100 sq in/ 24 hr, max	For use in general purpose packaging where a high degree of moisture resistance, moderate vapor resistance, and dust protection are required. Not intended for use where special grease or oil resistance properties are required
	Type II - High impact strength polyethylene			1700 psi	WVTR: 10 gm/ 100 sq in/ 24 hr, max	
	Type III - Polypropylene Class 1 - for non-food contact applications Class 2 - for use in food contact			1700 psi	WVTRL 10 gm/ 100 sq in/ 24 hr, max	
PPP-B-1055 BARRIER MATERIAL, WATERPROOF, FLEXIBLE	B-1--Baling and interior wraps			18		For use in packaging and packing applications which require waterproofness plus a high degree of resistance to permeation by water vapor.
	B-2--Baling and interior wraps			12		
	C-1--Interior wraps			20		
	C-2(a)--Crate liners & interior wraps			36		
	E-1--Interior wraps & crate liners			36		
	E-2--Interior wraps, crate liners, shrouds & balancing			36		
	H-1--Case liners, shrouds & crate liners		400	12		
	H-2--Case liners		400	25		
	H-3(a)--Case liners			32		
	H-4--Case liners			28		
	H-5--Case liners, shrouds & crate liners		400	12		

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TABLE 8-1
SPECIFICATION REQUIREMENTS FOR BARRIER MATERIALS[9] (Cont.)

Specifications	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
PPP-B-1055 (Continued)	L-2(b)--Case liners & crate liners			36		
	L-4--Temporary tarpaulin			36		
	M-1--Case liners, shrouds & crate liners.					

TABLE 8-2
PROPERTIES OF PACKAGING FILMS[10]

Material→		Nylon 6	Nylon 66	Nylon 610	Nylon 12	Polycarbonate	Polyester[a]	Polystyrene (oriented)
GENERAL CHARACTERISTICS	**ASTM**							
Method of Production	—	Extr	Extr	Extr	Extr	Extr, cast	Extr	Extr
Forms Available	—	Sheets, rolls, tapes	—	—	Sheet, rolls, tapes	Sheet, rolls	Sheet, rolls	Sheet, rolls
Clarity	—	Transp	Transp	Transp, transl	Transp, transl	Transp, transl	Transp, opaque	Trp, trl, opaque
Min Thickness, in.	—	0.0005	—	—	0.0005	0.0005	0.00015	0.001
Max Width, in.	—	120	—	—	120	54	55	40
Area Factor, 1000 sq in./lb/mil	—	24.5	24.3	25	27.3	23.1	20	26.1
PHYSICAL AND MECHANICAL PROPERTIES								
Specific Gravity	D792	1.12	1.14	1.11	1.01	1.20	1.39	1.05–1.07
Tensile Strength, 1000 psi	D882	9–13	12	10	7-9	8	17–18	7–12
Elongation, %	D882	>400	>250	>250	120-350	85–105	70–130	3–10
Burst Str (Mullen), psi	D774	—	—	—	—	25–35	45	30–60
Tear Str (Elmendorf), gm/mil	D689	50	50	70	—	10–16	18	2–8
Fold Endurance	D643	Exc	Exc	Exc	Exc	250–400	Exc	—
Heat Sealing Range, F	—	400–450	490–540	420–470	350–400	400–430	490	220–300
Water Absorp (24 hr), %	D570	8.0	1.5	0.4	0.25	0.35	Nil	0.04–0.06
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	18.0[b]	—	—	3.6-4.6	8.0	1.8	6.2
Gas Perm, cu cm/100 sq in./24 hr/mil	—							
Oxygen		2.6	2.5	4.5	51-89	142	5.7	213
Nitrogen		—	0.7	—	13-18	28	0.9	42
Carbon Dioxide		—	11	—	152-330	680	17.5	926
ELECTRICAL PROPERTIES								
Dielec Str (77F, 60 cps), v/mil	D149	480	385	470	—	3200	7500	400–600
Dielec Const (77F, 60 cps)	D150	4.8	4.0	3.6	4.2	3.09	3.25	2.4–2.7
Dissip Factor (77F, 60 cps)	D150	0.014–0.040	—	—	0.009	0.0003	0.0021	0.005
Surface Res, ohm	D257	—	—	—	6×10^{12}	1.4×10^{12}	$>1 \times 10^{17}$	—
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Poor	Poor	Poor	P–G	Good	Exc	Good
Strong Alkalis	—	Exc	Exc	Exc	Exc	Poor	Exc	Exc
Greases and Oils	—	Exc	Exc	Exc	Exc	Good	Exc	Good
Solvents	—							
Ketone and Ester		Exc	Exc	Exc	Exc	Fair	Exc	Poor
Chlorinated		—	—	—	Poor	Poor	Exc	Good
Hydrocarbon		Exc	Exc	Exc	Exc	Fair	Exc	Good
ENVIRONMENTAL PROPERTIES								
Max Cont Service Temp, F	—	380	300	300	230	270–280	250	160–180
Min Service Temp, F	—	<−100	<−100	<−100	−100	<−212	−80	—
Resistance to Sunlight	—	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Dimensional Change, %	—	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Storage Stability	—	Exc	Exc	Exc	Exc	Exc	Exc	Good
Rate of Burning	—	Self-ext	Self-ext	Self-ext	Self-ext to slow burn	Slow	Self-ext	Slow

[a]Polyethylene terephthalate. [b]Procedure E.

TABLE 8-2
PROPERTIES OF PACKAGING FILMS[10] (Cont.)

Type →		Cellophane		Fluorocarbon			Polypropylene	
		Plain	Coated	CTFE	FEP	PVF	Set Cast	Biaxially Oriented
GENERAL PROPERTIES	ASTM							
Method of Production[a]		Extr	Extr	Extr	Extr	Extr	Extr, calndr	Extr
Forms Available		Sheet, rolls, tapes	Sheet, rolls	Rolls	Rolls	Rolls	Sheets, rolls, tapes	Sheets, rolls
Clarity[b]		Trp	Trp	Trp	Trp	Trp	Trp	Trp
Min Thickness, in.		0.0009	0.0009	0.0005	0.005	0.0005	0.00075	0.0005
Max Width, in.		60	46	48	48	48	60	72
Area Factor, 1000 sq in./lb/mil		12-22	12-25	13.5	13	7	31	31
PHYSICAL PROPERTIES								
Specific Gravity	D792	1.45	1.40-1.55	2.1	2.15	1.5	0.90	0.90
Ten Str, 1000 psi	D882	8-19	7-16	5-8	3-3.5	7-18	4-10	18-32
Elong, %	D882	15-25	15-50	50-150	300-400	115-250	>400	40-80
Burst Str (Mullen), psi	D774	45-70	45-70	23-31	10-15	19-70	—	—
Tear Str (Elmendorf), gm/mil	D689	2-10	2-15	10-26	100-150	12-100	20-100	5-10
Fold Endurance	D643	7000-22,000	—	Good	4000	—	Excellent	Excellent
Heat Seal Range, F		Not sealable	200-350	370-500	600-700	—	320	—
Water Absorp (24 hr), %	D570	High	High	Negligible	0.01	0.05	Negligible	Negligible
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	High	0.2-1.0	0.025	0.40	—	0.4-1.0	.25-.5
Gas Perm, cu cm/100 sq in./24 hr/mil								
Oxygen		2	Low	7-12	950	3.2	150	150
Nitrogen		3	Low	2.5	360	0.3	—	—
Carbon Dioxide		39	Low	16-40	1850	11.1	—	—
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Poor	—	Excellent	Excellent	Excellent	Excellent	Excellent
Strong Alkalis		Poor	—	Excellent	Excellent	Excellent	Excellent	Excellent
Greases and Oils		Excellent	—	Excellent	Excellent	Excellent	Good	Good
Solvents								
Ketone and Ester		Excellent	—	Good	Good	Excellent	—	—
Chlorinated		Excellent	—	Good	Good	Excellent	—	—
Hydrocarbon		Excellent	—	Excellent	Excellent	Excellent	Good	—
PERMANENCE								
Max Cont Svc Temp, F		375	300-375	300-390	400	225	285	—
Min Svc Temp, F		0	0	−320	−400	−100	—	<−40
Resistance to Sunlight		Good	Good	Excellent	Excellent	Excellent	Fair	Fair
Dimensional Change, %		3-5	2-5	Nil	Nil	Nil	Nil	—
Storage Stability		Good	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Flammability (rate of burning)		Fast	Fast	Nil	Nil	Slow	Slow	Slow

[a]Key: cast = casting; calndr = calendering; extr = extrusion. [b]Key: trp = transparent; trl = translucent.

TABLE 8-2
PROPERTIES OF PACKAGING FILMS[10] (Cont.)

Material →	ASTM	Polyethylene Type I	Polyethylene Type II	Polyethylene Type III	Polyvinyl Chloride (incl copolymers) Rigid	Polyvinyl Chloride (incl copolymers) Nonrigid	Rubber Hydro-chloride	Polyimide
GENERAL CHARACTERISTICS	**ASTM**							
Method of Production	—	Extr, calndr	Extr, calndr	Extr	Cast, calndr, extr	Cast, calndr, ext	Cast	Cast
Forms Available	—	Sheets, rolls, tapes, tubes	Sheets, rolls, tapes	Sheets, rolls, tapes	Sheets, rolls, tapes	Sheets, rolls, tapes, tubes	Sheets, rolls, tapes	Sheets, rolls, tapes
Clarity	—	Transp, transl, opaque	Transp, transl, opaque	Transp, transl	Transp, transl, opaque	Transp, transl, opaque	Transp, transl, opaque	Transp
Min Thickness, in.	—	0.00075	0.00075	0.00075	0.001	0.005	0.0004	0.0005
Max Width, in.	—	72	60	60	54	104	60	—
Area Factor, 1000 sq in./lb/mil	—	30	30	29	19.5–22.5	20–23	24	19.4
PHYSICAL AND MECHANICAL PROPERTIES								
Specific Gravity	D792	0.92	0.935–0.938	0.940–0.945	1.36–1.50	1.15–1.50	1.12–1.15	1.42
Tensile Strength, 1000 psi	D882	1.6–3.0	2.5–3.5	3.5–8.0	6.5–8.5	1–5	5–6	24–25
Elongation, %	D882	300–800	>200	50–400	5–25	50–500	350–500	65–70
Burst Str (Mullen), psi	D774	10–15	—	—	—	9–20	—	75
Tear Str (Elmendorf), gm/mil	D689	100–125	93–97	10–350	20–150	30–1400	1000–1500	—
Fold Endurance	D643	Good	Good	Good	Poor	Good	—	Good
Heat Sealing Range, F	—	400–450	250–375	250–375	260–400	200–400	225–350	Not poss
Water Absorp (24 hr), %	D570	0.01	Neglig	Neglig	Neglig	Neglig	Neglig	2.9
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	1.5	0.5–0.7	0.3–0.4	0.5 (0.005 in.)	0.7 (0.005 in.)	0.5–15.5	5.4
Gas Perm, cu cm/100 sq in./24 hr/mil	—							
Oxygen		5.50 (1 mil)	280 (1 mil)	200 (1 mil)	3 (0.005 in.)	—	2–405	25
Nitrogen		300 (1 mil)	—	42 (1 mil)		—	—	6
Carbon Dioxide		2500 (1 mil)	990 (1 mil)	580 (1 mil)	11 (0.005 in.)	—	36–2616	45
ELECTRICAL PROPERTIES								
Dielec Str (77 F, 60 cps), v/mil	D149	450	450	500	250–1300	250–1300	—	7000
Dielec Const (77 F, 60 cps)	D150	2.3	2.3	2.3	3.0–8.0	3.0–8.0	—	3.5 (1000 cps)
Dissip Factor (77 F, 60 cps)	D150	0.0005	0.0005	0.0005	0.009–0.16	0.009–0.16	—	0.003 (1000 cps)
Surface Res, ohm	D257	$>10^{14}$	$>10^{14}$	$>10^{14}$	—	—	—	$>10^{14}$
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Exc	Exc	Exc	Exc	Exc	Good	Exc
Strong Alkalis	—	Exc	Exc	Exc	Exc	Exc	Good	Poor
Greases and Oils	—	Fair	Fair	Fair	Good	Fair	Exc	Exc
Solvents	—							
Ketone and Ester		Good	Good	Good	Poor	Poor	Fair	Exc
Chlorinated		Fair	Fair	Fair	Fair	Fair	Fair	Exc
Hydocarbon		Fair	Fair	Fair	Exc	Good	Exc	Exc
ENVIRONMENTAL PROPERTIES								
Max Cont Service Temp, F	—	180	230	250	200–220	150–180	205	550
Min Service Temp, F	—	—70	<—100	<—100	—70	—50	—20	—450
Resistance to Sunlight	—	Fair	Fair	Fair	Good	Good	Fair	Exc
Dimensional Change, %	—	Nil	Nil	Nil	Nil	Nil	Slight	Nil
Storage Stabiltiy	—	Exc	Exc	Exc	Exc	Exc	Good	Exc
Rate of Burning	—	Slow	Slow	Slow	Self-ext	Self-ext	Self-ext	Self-ext

TABLE 8-3
WRAPPING AND MARKING CHARACTERISTICS OF PACKAGING FILMS

	Workability	Marking Ease	Sealing Method	Heat Shrinkable
Cellophane				
Plain	Excellent	Good	Adhesives	No
Coated	Excellent	Good	Heat or adhesives	No
Fluorocarbon				
CTFE	Good	Good[1]	Heat	No
FEP	Good	Good	Heat or adhesives[1]	No
PVF	Good	Good	Adhesives	Yes
Nylon	Good	Good	Heat	No
Polypropylene				
Set cast	Fair to good	Good	Heat	No
Biaxially oriented	Fair to good	Good	Heat or adhesives	Yes
Polycarbonate	Good	Good	Heat or adhesives	No
Polyester	Good	Good	Heat[2] or adhesives	Some types
Polystyrene (oriented)	Good	Good	Heat or adhesives	Yes
Polyethylene	Fair to good	Good[1]	Heat	Some types
Polyvinyl Chloride	Fair	Good[1]	Heat or adhesives	Some types
Rubber Hydrochloride	Fair	Good	Heat	Some types

1. Requires special ink or must be specially treated

2. Requires special coating

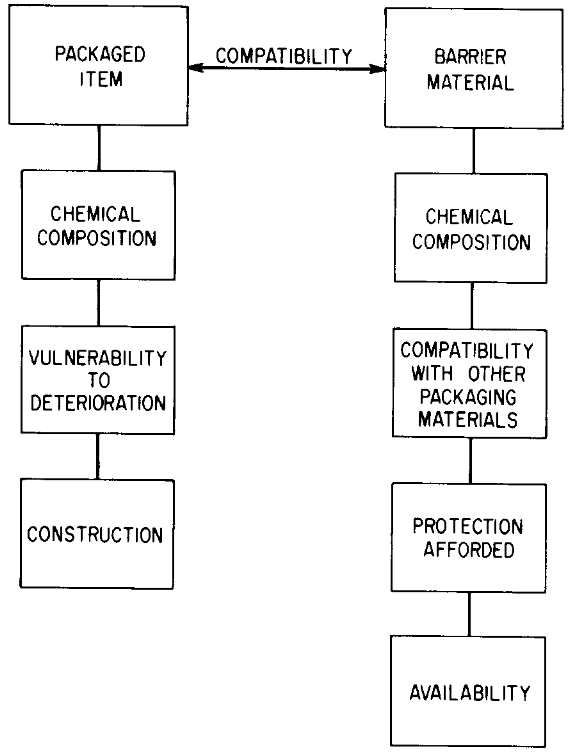

Fig. 8-1. Selecting a Barrier Material

8-1.3 ITEM CHARACTERISTICS

The item characteristics that must be considered when choosing a barrier material are:

a. *Chemical Composition.* The barrier material and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the barrier material.

b. *Vulnerability to Deterioration.* The major types of deterioration and the degree to which the item is vulnerable must be known in order for the barrier material to provide adequate protection. The vulnerability of the barrier material must also be considered.

c. *Construction.* The major dimensions of the item must be known for determining the amount of barrier material and the type, sheet, bag form, or rigid container form that is required.

8-1.4 BARRIER MATERIAL CHARACTERISTICS

The barrier material characteristics that must be considered when choosing a barrier material are:

a. *Chemical Composition.* The barrier material and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the barrier material.

b. *Compatibility With Other Packaging Materials.* The barrier material must be compatible with all other packaging materials with which it may come in contact, including preservatives and the outer wrap to prevent harmful interaction that may affect the integrity of the package.

c. *Protection Afforded.* The protection afforded by a barrier material must be commensurate with the types of deterioration to which the item is vulnerable.

d. *Availability.* The availability of the barrier material must be known. If special equipment is required for applying the barrier material, it must be available and be suitable for use with the item.

8-1.5 STATIC CONDUCTIVITY IN PLASTIC FILMS

Unpleasant and sometimes dangerous electrostatic charges can build up on flexible plastic films. These charges are generated by friction from the film rubbing either against itself or against other nonmetallic materials. This may occur during packaging or afterward.

Static charges on large sheets of film can result in dangerous sparking, attraction and holding of dust or other undesirable particles, or merely nuisances such as unpleasant shocks and difficulty in handling the film because of clinging.

Electrical discharge should be a prime factor when considering barrier materials in the packaging of highly flammable materials, explosive chemicals, or munitions. Generally, some nonplastic barrier material should be used in these cases.

Conductive plastic films and barriers made with such films are now commercially available and may be used in some applications where requirements for electrostatic-free packaging exist.

Highly sophisticated parts such as used in missile or electronic systems are especially susceptible to foreign particles which may adhere to films. When plastic films are used, special precautions should be taken to insure their cleanliness.

8-2 CUSHIONING

If items are subject to damage from impact, vibration, or simply from abrasion, they will require protection within the shipping container. There are numerous types of cushions ranging from excelsior and cellulosic wadding to springs and elaborate mechanical shock mounts. The paragraphs which follow discuss the functions of cushioning, the materials commonly used as cushions, and their applications.

8-2.1 PURPOSE

The purpose of cushioning is to insure adequate protection of the contents of a pack or package under particular circumstances such as:

a. Protection of delicate and fragile items against the effects of shock and vibration occurring during handling and transportation.

b. Protection of delicate and highly finished surfaces against abrasion.

c. Protection of small projections on items.

d. To prevent rupture or severe abrasion of greaseproof or waterproof barriers at points of contact with solid blocks or braces.

e. Protection of moisture-vaporproof barriers, at points of contact, from sharp edges of the item itself, packing materials, or container.

f. Protection at points of contact with wood blocking or bracing, and protection of strippable compound coating applied to large or heavy items.

g. To absorb liquids.

8-2.2 PROPERTIES

8-2.2.1 Shock Absorption and Resilience

The properties of shock absorption and resilience vary for specific materials. One material may be an excellent cushion when used to protect small, light, fragile items, but this same material may be unsatisfactory when used to protect small, heavy, fragile items. The cushioning material must be able to absorb a series of shocks and must have ability to return to its original size and shape after each deformation. Cushioning material that settles down so that looseness develops is not entirely satisfactory. The tendency for a material to become permanently compressed under initial loadings can be offset to some extent by precompressing it when the item is packed.

8-2.2.2 Texture and Workability

The ability of cushioning materials to protect finished surfaces against abrasion is dependent on the texture of the materials. Materials such as creped cellulose wadding or cotton wadding are soft textured and can generally be placed in contact with easily marred surfaces. Generally, materials supplied in roll form are sufficiently pliable to be used without difficulty to cushion irregularly shaped items. These materials are readily used to make irregular surfaces regular and are used for wrapping small miscellaneous parts.

8-2.2.3 Water Resistance

Generally, hygroscopic cushioning materials will have less protective or cushioning value at high moisture content than at low moisture content. For this reason absorbent materials must be protected from long exposures to high humidities by means of a sealed water-vaporproof barrier. Water-resistant materials respond less rapidly to moisture changes and should always be used when the application of a water-vaporproof or waterproof barrier is not feasible. Most cushioning, when wet, will cause corrosion of contacting metal surfaces. Greaseproof or water-vaporproof barriers are recommended to separate cushioning materials from metal surfaces. Fig. 8-2 illustrates types of waterproof barriers.

8-2.2.4 Resistance to Dust

Small particles become detached, during use, from most cushioning materials. Items having operational functions that can be harmed by dust particles should

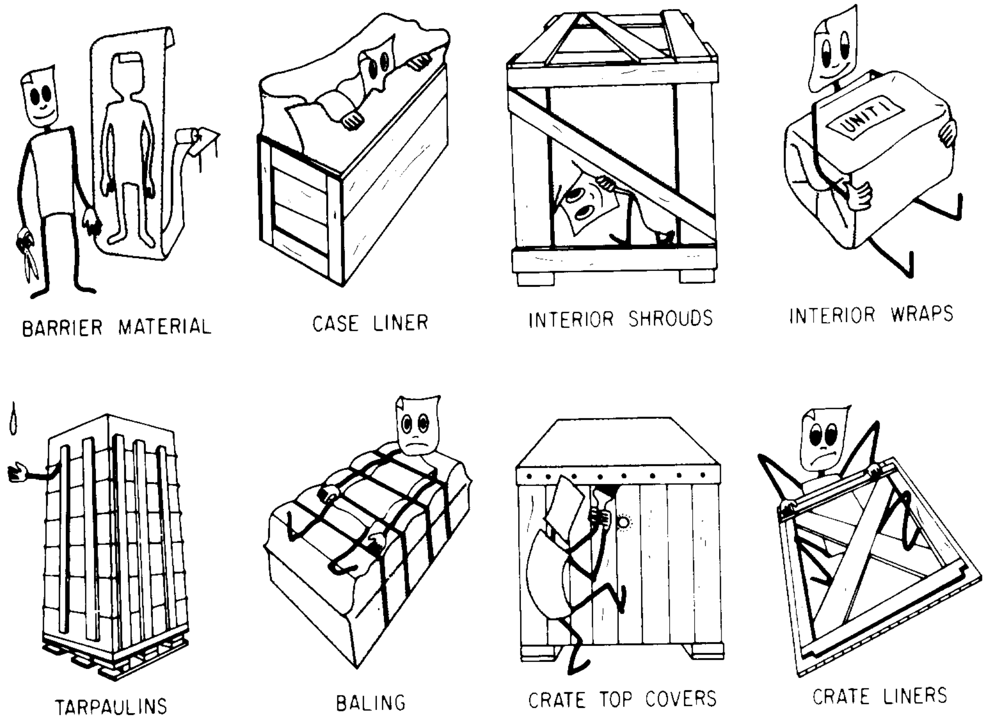

Fig. 8-2. Waterproof Barriers

be wrapped or protected by other means against the entrance of dust. Items that will not be protected when in service need not be protected against dust particles when packaged for shipment.

8-2.2.5 Fungus Resistance

Many cushioning materials can be made fungus-resistant by means of chemicals introduced during the manufacturing process. Materials so treated generally will not be affected by micro-organisms during exposure to atmospheric conditions in which fungi usually flourish. Treated materials, however, are often very corrosive to metal surfaces and need to be isolated from them.

8-2.3 SELECTING THE CUSHIONING MATERIAL

There are several factors that need to be considered in selecting the appropriate cushioning material for a specific application. To design the cushioning requirements rationally, the fragility of the item must be known and the level or performance in rough handling must be established for the item.

Since little is commonly known about the actual fragility of military materiel, only estimates can be made. For strategic military materiel, it is necessary to design for nearly 100 percent successful shipment. Because information is not available on the height of drop, kind of dropping surface, or probability of flat or edge drops that the item is likely to be subjected to during transportation, a height of drop is chosen for specifying the level of performance in handling operations based in general on item weight. Light, fragile instruments usually require the use of low density cushioning several inches thick having high resilience. The cushioning materials for heavy articles, however, need to be more dense and firm.

Harsh abrasive materials should never contact highly finished surfaces. Such surfaces should be isolated from the cushioning with a barrier. Also, cushioning must be separated from corrodible surfaces. When cushioning must be enclosed within moisture-vapor-proof barriers, cushioning with a low moisture content should be used. Cushioning used outside the barrier must retain a large portion of its cushioning properties when completely wet.

8-2.4 TYPES

Table 8-4 provides data on selected cushioning materials while Table 8-5 gives specifications for cushioning materials. Various cushioning materials, their

advantages, and limitations are discussed in the paragraphs which follow.

8-2.4.1 Flexible Corrugated Paper

Flexible corrugated paper is economical, easy to obtain, moldable, and provides good cushioning for some lightweight objects. The cushioning effect is provided by the corrugations being crushed. If loaded to the extent that the corrugations are completely crushed on a single fall, however, most of its resilience and cushioning property is lost.

8-2.4.2 Wool Felt

Felt material is available in a variety of thicknesses and densities, and can be used for most cushioning applications. It is especially adaptable for padding hold-down cradles and braces to prevent damage to the item being secured. Generally, the felt materials are resilient and will withstand repeated deformations and abrasions without disintegrating. The material may be procured in rolls of flat stock or die-cut pads of various shapes and thicknesses.

8-2.4.3 Glass-fiber

Glass-fiber cushioning materials may be procured in densities ranging from a fraction of a pound per cubic foot to 12 to 15 pounds per cubic foot. Many thicknesses of sheets or die-cut pads are available in the various densities. This inorganic material is one of the more resilient cushioning materials and is nonhygroscopic, fire-, mold-, and fungus-resistant as well as being resistant to most acids and alkalies. Although the fine fibers are easily handled, some grades are highly abrasive and susceptible to dusting, therefore, requiring isolation from finished surfaces and item openings when critical.

8-2.4.4 Cellulose Wadding, Cotton, and Wood-fiber Felt

Cellulose wadding, cotton, and wood-fiber felt may be used for lightweight, delicate objects, and these materials are available in thicknesses of 0.25 to 1.00 inch. They are readily moldable and fairly resilient. In combination with an overwrap of corrugated paper they form effective cushions to protect relatively heavier items from shock. Any items that may be damaged by lint or small fibers should first be wrapped to exclude lint. These materials, even when treated, are water absorbent and retain water in their pores; therefore, they must not be placed directly against metal surfaces. They should not be used on the outside of a waterproof or water-vaporproof barrier as they lose much of their cushioning properties when wet.

8-2.4.5 Excelsior

Excelsior is one of the oldest cushioning materials used. It is a good cushioning material when properly used. Also, it is relatively economical and available. When improperly used, wood particles and dust may enter machined parts or assemblies, or highly finished surfaces may be scratched by it. Humid conditions have less effect on its cushioning qualities than on many other materials, but dampness together with exuded wood acids may corrode metal contacting it. It should have a moisture content of about 12 to 18 percent to be most efficient as a cushioning material, because when very dry it frequently disintegrates into fine particles. For these reasons, excelsior is best used when it is made up into sealed pads covered with waterproof paper, or as a cushioning layer between the walls of an outer and inner container. When excelsior is used, the required density or weight of the excelsior is determined by the pressure imposed by the item on each square inch of load bearing area. Excelsior is highly flammable and under certain conditions spontaneous combustion is possible.

8-2.4.6 Hair or Fiber and Rubber

Rubber-coated and impregnated fibrous products are lightweight, resilient, and have low compression-set characteristics as compared to other nonrubber-base cushioning materials. They are very widely used in military packaging. Animal hair or vegetable fiber bonded with rubber is usually provided by the manufacturer in sheet form, but it may be furnished molded into the required shape and thickness for a specific article. Intricate shapes should be molded since the material cannot, as a rule, be efficiently fabricated to fit the item at the packing line. The molded forms are often used with reusable containers and generally the molded forms may be used several times.

8-2.4.7 Foamed Sponge Rubber

Foamed sponge rubber is particularly adaptable to the cushioning of items that might otherwise be damaged by dust from other cushions. Generally, it is highly resilient and its cushioning properties are not materially affected by moisture. It is a relatively expensive product, but it may be reused. Sponge rubber may be produced in molded forms for intricately shaped articles. Also, it may be furnished in flat sheets of various densities and thicknesses.

TABLE 8-4
GENERAL PROPERTIES OF SELECTED CUSHIONING MATERIALS[13]

Material	Compression set	Damping shock absorption [1]	Density	Dusting	General corrosive effect	Moisture Absorption	Moisture content	Fungus resistance [4]	Low-temperature function
Animal hair, bonded sheet molded	Slight	Good	Varies	Slight	Slight	Slight	High	Poor	Fair [5]
Foam rubber, molded	Slight	Good	High	Some	Slight	Much	High	Poor	Good
Blown vinyl flexible foam	Some	Good	High	None	Slight	Much	Low	Good	Poor
Air pillow—vinyl cradle	None	Fair	Low	None	None	None	None	Excellent	Good
Vinyl cradles in suspension	None	Fair	Low	None	None	None	None	Excellent	Good
Springs	Neglig.	Poor	----------	None	None	None	None	Excellent	Good
Canvas slings	Neglig.	Fair	----------	None	None	Some	Varies	Poor	Good
Honeycomb, Kraft paper	Much [3]	Excellent [3]	Low	None	Slight	Medium	Low	Poor	Good
Excelsior[6]	Much	Excellent	Average	Very high	Much	High	High	Poor	Poor
Shredded paper[6]	Much	Excellent	Average	Very high	Much	High	Varies	Poor	Good
Corrugated fiberboard [2]	Much	Excellent [3]	Low	Slight	None	High	Varies	Poor	Good
Plastics foams:									
Polyethylene, molded	Slight	Excellent	Average	Slight	None	Low	None	Good	Good
Polystyrene, Molded	Varies	Good	Low	Slight	None	Slight	Low	Good	Good
Strands	Slight	Excellent	Low	Slight	None	Slight	Low	Good	Good
Resilient sheet	Slight	Excellent	Low	Slight	None	Slight	Low	Good	Good
Polyurethane, rigid	Much	Excellent	Varies	High	None	Low	Low	Good	Good
Polyurethane, flexible	Slight	Excellent	Varies	Slight	None	High	High	Good	Poor
Cellulose wadding:									
Creped	Much	Excellent	Average	Much	None	Varies	Low	Poor	Good
Homogeneous	Varies	Excellent	Varies	Varies	None	Varies	Low	Poor	Good
Cotton	Much	Excellent	Low	Much	None	Much	Varies	Poor	Good
Plant fibres, rubber bonded	Slight	Fair	Average	Slight	Slight	Slight	Low	Poor	Fair
Fibreglas	Slight	Fair	Average	Slight	Slight	Slight	Low	Good	Good

[a] Ratings shown are general. Properties differing from those given here can vary greatly according to type of material, amounts used, and conditions of use. Consult producers regarding specific requirements.
[1] Capacity of cushion to absorb and not transmit shock.
[2] Values for flutes in column or flat.
[3] Shock absorption declines as material crushes under repeated shock.
[4] Many treatments are used to avoid problem of poor fungus resistance.
[5] Good when treated.
[6] Highly flammable.

TABLE 8-5
SPECIFICATIONS FOR CUSHIONING MATERIALS

C-F-202	*Felt Sheet (Hair) and Felt Roll (Hair)*
PPP-P-150	*Paper, Shredded Waxed*
PPP-P-291	*Paperboard, Wrapping, Cushioning*
PPP-C-00795	*CushioningMaterial, Cellular,Plastic Film (For Packaging Applications) Applications)*
PPP-C-843	*Cushioning Material, Cellulosic*
PPP-C-850	*Cushioning Material, Polystyrene, Expanded, Resilient (For Packaging Uses)*
PPP-E-911	*Excelsior, Wood, Fabricated Pads and Bulk Form*
PPP-C-1120	*Cushioning Material, Uncompressed Bound Fiber for Packaging*
MIL-B-3106	*Board, Composition, Water-Resistant, Solid (for Filler or Cushioning Pads)*
MIL-R-6130	*Rubber, Cellular, Chemically Blown*
MIL-P-13607	*Padding Materials, Resilient (For Packaging of Ammunition)*
MIL-C-17435	*Cushioning Material, Fibrous Glass*
MIL-P-19644	*Plastic Foam, Molded Polystyrene (Expanded Bead Type)*
MIL-C-23734	*Cushioning Material Cellulosic, Treated, Free Flow, Tubular*
MIL-C-26296	*Cushioning Material, Packaging, Synthetic Fibers*
MIL-P-26514	*Polyurethane Foam, Rigid and Elastic, for Packaging*
MIL-C-26861	*Cushioning Material, Resilient Type, General*
MIL-C-26862	*Fiberboard, Solid, Dunnage, Multipurpose Cushioning and Blocking Applications*
MIL-C-40010	*Cushioning Material, Polyvinyl Chloride Plasticized, Cellular*
MIL-C-46842	*Cushioning Material, Unicellular Polyethelene Foam (For Packaging Purposes)*
MIL-C-81013	*Cushioning Materials, Transparent, Flexible, Cellular, Plastic Film, For Packaging Applications*

8-2.4.8 Unicellular Sponge Rubber

This cushioning material is a special type of sponge rubber, chemically blown under pressure to produce a uniform noninterconnecting cell structure. It has high resilience, since each cell acts as an individual air cushion. It is best used as a bumper pad where it occasionally receives impact loads. It also has an important value as an insulating material or a flotation material since it is extremely buoyant.

8-2.4.9 Shredded Paper

Shredded paper–such as newsprint, waxed paper, or cellophane–is economical and easy to obtain. It is adversely affected by water, and may absorb and retain moisture through wicking action unless protected. It will not prevent an item from ultimately settling against the face of the container, and should be used only for light, bulky items. It is available in wrapped pad forms that may have moisture barriers. Shredded paper is highly flammable and under certain conditions spontaneous combustion is possible.

8-2.4.10 Mineral Wool

Mineral or rock wool is fireproof and water resistant. It is dusty, hard to handle, and may produce skin irritation. Mineral wool should never be placed directly in contact with surfaces which can be damaged by abrasion.

8-2.4.11 Foamed (Cellular) Plastics

Foamed plastic cushioning materials are a recent innovation in packaging. Their light weight and excellent shock damping properties make them well suited for this purpose. Additional properties which make them desirable as cushioning materials are described in Table 8-4. Many types of foams are available with a wide range of properties to fit most packaging needs.

Foamed plastics may be obtained flexible or rigid and with densities varying from 0.1 to 60 lb/ft (Ref. 3). Some are available in open or closed cell foams. Open cell foams are more resilient but are subject to moisture absorption. Closed cell foams may be flexible or rigid and are generally free from any appreciable moisture absorption.

The nine general types of plastics used for foam-making are: (1) cellulose acetate, (2) epoxies, (3) phenol-formaldehyde, (4) polyethylene, (5) polystyrene, (6) silicones, (7) urea-formaldehyde, (8) urethanes, and (9) vinyls.

Of the listed foams, those most frequently used in packaging are polyurethane, polyethylene, and polystyrene.

Foams come in many different forms. They may be obtained premolded to any desired shape; in a slab; sheet, or block form; and in some cases they may be foamed in place. However, it must be kept in mind that foam-in-place produces excessive heat and may not be satisfactory for packaging certain items. Sheet, block, and slab stock are easily cut and shaped into almost any desirable configuration needed for cushioning or blocking. Adhesives are available for bonding these foams to containers or barriers. See Chapter 12 for applicable adhesives.

Foam-in-place plastics, primarily rigid polyurethanes, are the result of mixing the plastic ingredients under the action of catalysts and the introduction or generation of a blowing agent during the mixing. This mixture is poured into the mold or cavity to be filled and, upon expansion, fills all voids or cavities of the mold. As the material foams, it adheres strongly to all surfaces and eliminates any need for adhesives.

By use of the foam-in-place method, an item to be packaged may be placed in its shipping container and the foam chemicals poured or pumped into the container. When the foaming has been completed, the item is completely encased in a waterproof cushion exactly conforming to the shape of the item and the shipping container. Excellent blocking or bracing protection is thus obtained in addition to some degree of cushioning.

Mixing can be as simple as hand batching the ingredients in a pail and pouring them into the cavity to be filled. For other applications, spraying with a gun may be used, or frothing may be employed. In frothing, the blowing agent is introduced into the chemicals under pressure before they are mixed. In this way, expansion is started before the chemical reaction takes place. This produces a foam of very low density. Equipment required for these processes include chemical metering devices, mixing devices, in some cases an aerating system for the blowing agent, and an applicator device such as a spray gun, nozzle, or pump.

Foam-in-place plastics are showing increased usage in areas where costs are justified based on labor and material savings. The requirement for special equipment suggests an application where a moderate production run of like items will warrant the setup and maintenance time necessary. There are presently situations where extensive labor time is being expended on certain items for forming complex blocking and bracing systems. In cases like these, foam-in-place may provide an answer by greatly reducing total packaging costs. Ref.

14 provides a detailed method for foam-in-place application.

A complete discussion of plastic foams, their characteristics, chemical formulation, and methods of application are contained in Refs. 11 and 12.

REFERENCES

1. MIL-B-121, *Barrier Material, Greaseproofed, Waterproofed, Flexible.*
2. MIL-P-130, *Paper, Wrapping, Laminated and Creped.*
3. MIL-B-131, *Barrier Material; Water-Vaporproof, Flexible, Heat Sealable.*
4. MIL-A-148, *Aluminum Foil.*
5. UU-P-268, *Paper, Kraft, Untreated, Wrapping.*
6. PPP-B-1055, *Barrier Material, Waterproofed, Flexible.*
7. MIL-B-13239, *Barrier Material, Waterproofed, Flexible, All Temperature.*
8. MIL-P-17667, *Paper, Wrapping, Chemically Neutral.*
9. NNN-P-40, *Paper, Lens.*
10. *Materials Engineering,* Vol. 68, No. 5, pp. 229-231, *Materials Selector Issue,* 1968-1969.
11. MIL-HDBK-700(MR), *Plastics.*
12. *Modern Plastics Encyclopedia,* 1968.
13. TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. II.
14. AMCP 746-4, *Marking and Packaging of Supplies and Equipment Foamed-in-Place.*

CHAPTER 9

CONTAINER MATERIALS

This chapter provides information on the various materials that may be used as containers for military items. The data presented include general information on container types, as well as tables of properties and characteristics of common container materials. In addition, specifications covering the various types of materials are given. (This information supplements the general data given in par. 10-2.5.)

9-1 SELECTION OF CONTAINER MATERIALS

As discussed in Chapter 7, container materials must be in accord with the method of preservation prescribed. The selection of container materials will usually be governed by the following general criteria:

a. Compatibility and suitability of the materials to provide the degree of protection required for the item and to assure the proper functioning of the package or pack.

b. Economy and efficiency of the materials with regard to

(1) Simplicity and economy of application of material in procurement and field operations

(2) Ease and economy of removal of materials under field conditions

(3) Comparative procurement cost of materials

(4) Availability of the materials

c. Reduction of weight and cube

d. Standardization of materials and reduction of types, grades, and classes prescribed and used in the packaging of like or similar items.

Container selection considerations are illustrated in Fig. 9-1.

9-2 TYPES OF CONTAINER MATERIALS

A wide variety of materials is fabricated for use as containers. Fig. 9-2 categorizes the various types of containers and container materials. This chapter provides data on the following materials commonly used as military containers:

a. Metals

b. Fiberboard and paperboard

c. Wood, plywood, and paper overlaid veneer

d. Plastics and reinforced plastics.

The information given includes general physical properties, available forms of the materials, and ease or difficulty in working them. References to other documents are also provided to aid the packaging engineer in locating pertinent data on these and other materials. Detailed data are given in Tables 9-9 through 9-13.

9-2.1 METALS

Metal containers are particularly suitable for the preservation and packaging of delicate items, especially those such as instruments, generators, gyros, starters, and magnetos which require a high degree of protection. Because metal containers are structurally rigid, they are especially useful as reusable containers and for long-term storage of equipment. Also, they may be palletized for convenience in handling. When properly sealed, metal containers provide a simple and highly effective water-vapor barrier, and thereby provide a degree of protection for the item equal to that afforded by other types of Method II protection. The containers may be drums, cans, or pails.

The metals most commonly used for containers are steel, aluminum, and magnesium. Containers made from these metals, or from their alloys, are adaptable for most container applications except those in which transparency is a requirement. An important consideration in the use of metal as a container material is cost. Comparative prices of metals are shown in Table 9-1. Metals, although less expensive than reinforced plastics, are still fairly expensive and should be used only when a more economical container material will not satisfy the requirements of a particular application. Also, consideration must be given to the ease or difficulty of fabricating the metal into usable containers.

9-2.1.1 Steel

The high carbon steel alloys are strong but difficult to weld. Medium and low carbon steels, however, are weldable and may be worked with metal-working tools and equipment. Steel alloys are available in many forms including flat sheet, coiled sheet, plate, rods, and rolled structural shapes. The low-alloy, high-strength steels possess greater strength and hardness, although they are more difficult to work with. They are usually not required for packaging purposes.

Specific physical properties of steel relevant to containerization usage are given in Table 9-9. Additional information on steels and steel alloys is contained in Ref. 1.

Specifications covering steels which are commonly used for container fabrication are: QQ-S-741, *Steel, Carbon, Structural, Shape, Plate and Bar;* and QQ-S-698, *Steel, Carbon (Low Carbon) Sheets and Strips.*

9-2.1.2 Aluminum

Aluminum alloys are available in either a clad or bare form. The clad material has a surface coating of an aluminum alloy that is corrosion-resistant and provides electrolytic protection against corrosion of the core alloy.

The working of aluminum requires less energy than does the working of low carbon steel. Forms of pure aluminum that are available for fabrication include sheet, plate, wire, bar, rod, and tubing. Aluminum alloys are produced in the form of castings, extruded shapes, bar, rod, and wire. Welding decreases the strength of heat-treated material, but in many cases the weldments may be heat-treated to restore strength.

Various properties of aluminum alloys are listed in Table 9-2. More detailed physical properties of aluminum alloys relevant to their use in containers are given in Table 9-9. Additional data on aluminum and aluminum alloys can be found in Refs. 1 and 2.

Specifications covering aluminum alloys commonly used for container fabrication are:

a. QQ-A-200, *Aluminum Alloy Bar, Rod, Shapes and Tube, Extruded,* General Specification and Parts 1-13

b. QQ-A-225, *Aluminum Alloy Bar, Rod, Wire or Special Shapes, Rolled, or Cold Finished,* General Specification and Parts 1-13

c. QQ-A-250, *Aluminum Alloy Plate and Sheet,* General Specification and Parts 1-18

d. MIL-A-25994, *Aluminum Alloy Angles, Channels, I and Z Beams, Extruded or Rolled, Structural Shapes.*

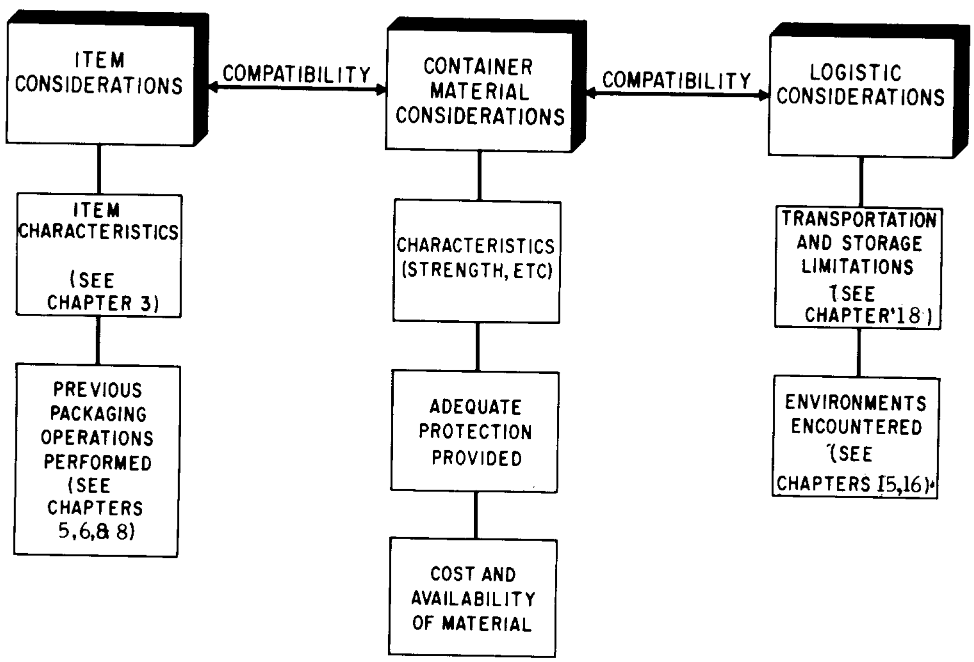

Fig. 9-1. Choosing a Container Material

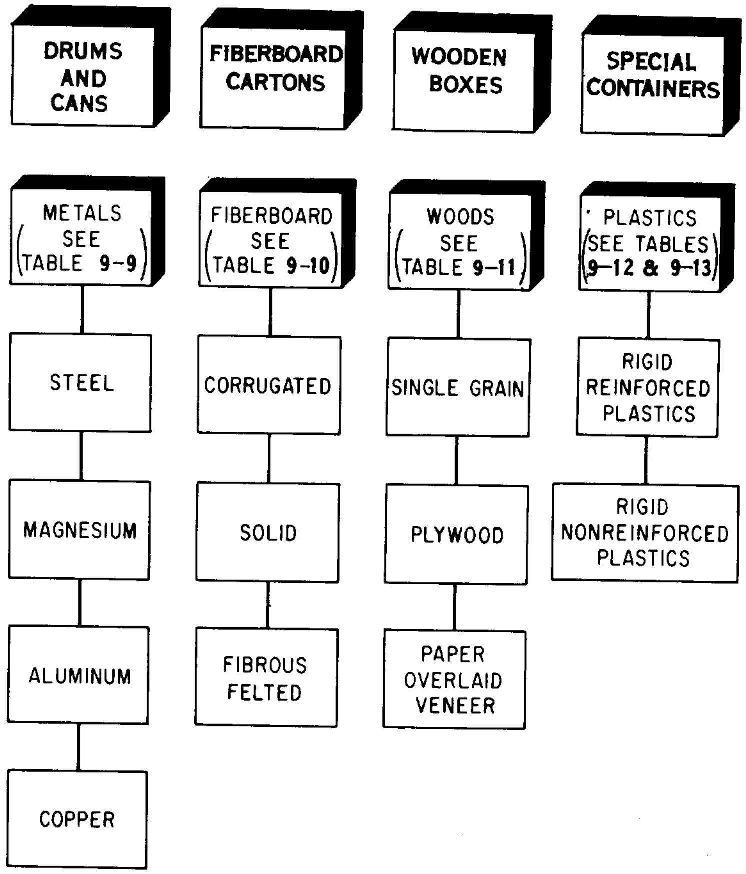

Fig. 9-2. Types of Containers and Container Materials

9-2.1.3 Magnesium

Magnesium alloys are lighter in weight than aluminum, and have similar working characteristics. Magnesium, however, is prone to crack more easily than aluminum during bending operations.

The alloys of magnesium are produced in various commercial forms including castings, sheet and plate, extruded shapes, and forgings. Magnesium structures are readily assembled by welding or riveting.

Mechanical and physical properties of magnesium alloys are given in Tables 9-3 and 9-4. The properties of magnesium alloys relevant to their use in containers are compared with those of other metals in Table 9-9. Refs. 1 and 3 provide additional data on magnesium and magnesium alloys.

Specifications covering magnesium alloys commonly used for container fabrication are:

a. MIL-M-26696, *Magnesium Alloy, Bar, Rod, and Special Shaped Sections, Extruded, PZK60B*

b. QQ-M-31, *Magnesium Alloy, Bars, Rods, and Special Shaped Sections, Extruded*

c. QQ-M-44, *Magnesium Alloy Plate and Sheet, AZ31*

9-2.2 FIBERBOARD AND PAPERBOARD

Fiberboard–because of its low cost, ease of fabrication, light weight, and ability to resist transportation hazards–is one of the most widely used container materials. Corrugated fiberboard is available in several forms of sheet stock including unlined, single- and double-faced board, double wall board, and triple wall board. Because corrugated fiberboard is a built-up structure, its characteristics depend upon the components used and their placement in the structure.

Since fiberboard boxes are, in general, a light type of container, every effort should be made to use them only for items falling within the weight and dimension limitations. Although fiberboard boxes are normally used to accommodate only loads that lend support to the

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container, wide use of blocking, bracing, and cushioning will convert many nonsupporting loads to supporting loads and permit the use of fiberboard. V-board and W-board should be used whenever possible because of their high strength and weather resistance.

Fiberboard cartons offer a number of advantages, namely:

a. Made of materials of exactly specified strength and water resistance

b. Made in various styles to suit various shapes and sizes of item

c. Shipped and stored in the flat, resulting in shipping and storage space savings

d. Easy to assemble and handle

e. High strength and light weight

f. When packed, they occupy less space than most other containers having the same interior dimensions.

Types of corrugated fiberboard are shown in Fig. 9-3 and minimum requirements for fiberboard containers are listed in Table 9-5. The properties of fiberboard relevant to containerization usage are given in Table 9-10.

Detailed design data regarding the use of fiberboard for shipping containers are contained in Ref. 4.

Some of the more commonly used fiberboard container specifications are:

a. PPP-B-591, *Box, Fiberboard, Wood-cleated*

b. PPP-B-636, *Box, Fiberboard*

c. PPP-B-640, *Box, Fiberboard, Corrugated, Triple-wall*

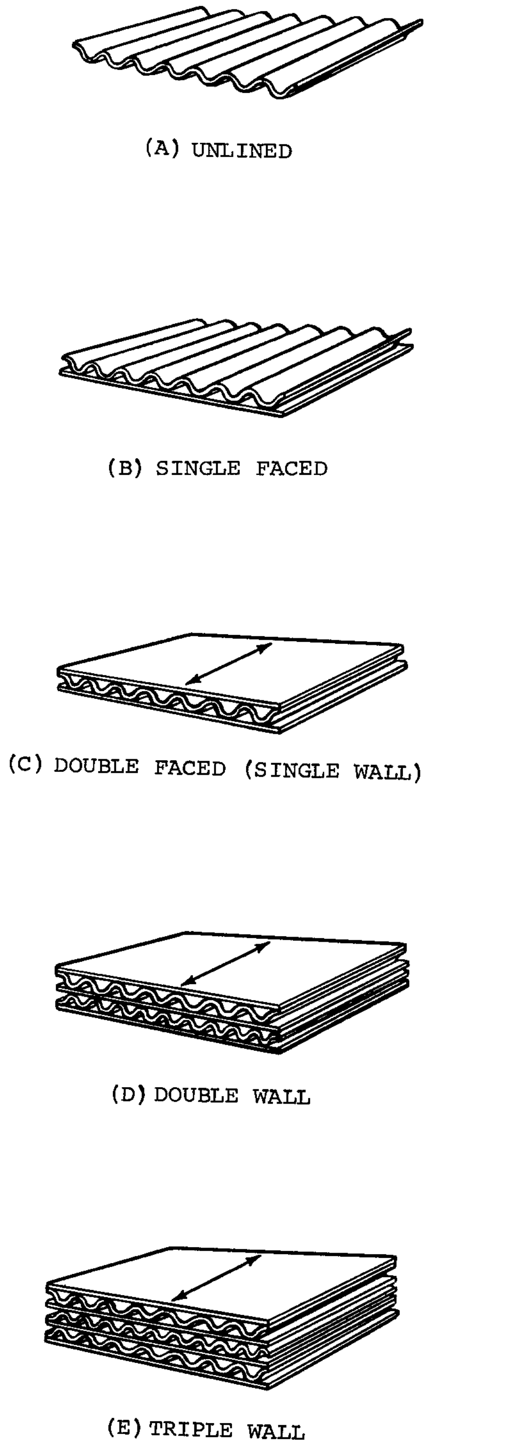
d. PPP-B-1163, *Box, Corrugated Fiberboard, High Compression Strength, Weather-resistant, Wax-resin Impregnated*

e. PPP-B-1364, *Box, Corrugated Fiberboard, High Strength, Weather-resistant, Double-wall*

f. MIL-B-43291, *Boxes, Fiberboard, Corrugated, Doublewall, Weather-resistant.*

Fiberboard boxes and drums may be used as exterior containers. Fiberboard drums are intended primarily for packaging powdered, granular, or flaked materials, or for hot-poured materials that solidify on cooling to atmospheric temperature.

Paperboard containers should be prescribed only for use as unit containers to provide protection to the contents or for convenience in handling; they are *not* to be used as external containers. Usually they are intended for items weighing not more than 10 lb. Because they lack waterproof qualities, they must be protected by suitable means whenever conditions require. Paper-



NOTE THAT CORRUGATION DIRECTION INDICATION ARROW PARALLELS THE PEAKS AND VALLEYS

Fig. 9-3. Types of Corrugated Fiberboard

TABLE 9-1
COMPARATIVE PRICES OF METALS[10]

Material	Cost, $/lb
Steel	
Carbon steel; hot-rolled sheet, strip, plate, bar	0.05 - 0.07
Carbon steel; cold-rolled sheet, strip, bar	.07 - .10
High-strength low-alloy steels; sheet, plate	.05 - .10
Alloy steels; cold-rolled strip	.15 - .18
Galvanized steel (hot-dipped); sheet	.08
Stainless Steel	
201, 202	.36 - .54
301, 302, 303, 304	.38 - .64
Aluminum and Its Alloys	
1100, 3003H; 0.030- to 0.249-in. thick sheet	.44 - .47
Magnesium Alloys	
AZ31B; sheet, plate	.70 - 1.98

NOTE: Costs are for comparison only since metal prices are subject to frequent change.

board containers may be in the form of folding setup, or metal-stayed boxes.

Folding boxes of various styles, types, and classes are made of bending grade paperboard having a thickness between 0.045 and 0.16 in. They are received flat or collapsed ready for mechanical or hand setup and use.

Setup boxes are made of nonbending grade paperboard having a thickness between 0.026 and 0.048 in. They are received already set up or collapsed ready for mechanical or hand setup and use.

Paperboard boxes may also be made of one or more paperboard flats assembled with metal stays.

Commonly used paperboard container specifications are:

a. PPP-B-566, *Box, Folding, Paperboard*

b. PPP-B-676, *Box, Setup*

c. MIL-B-19880, *Box, Paperboard, Metal-Stayed, Reusable*

d. PPP-B-665, *Boxes, Paperboard, Metal Stayed*

e. MIL-B-43014, *Boxes, Water Resistant, Paperboard, Folding, Setup and Metal-Stayed.*

9-2.3 WOOD, PLYWOOD, AND PAPER OVERLAID VENEER

Wooden boxes and crates make satisfactory containers for equipment that can be damaged easily. The advantages of wooden boxes and crates include the following five points:

(1) Maximum protection for contents against damage from puncture, distortion, or breakage

(2) Ability to support loads resulting from stacking during transit and storage

(3) Ability to contain difficult loads without undue distortion

(4) Adaptability to complex wood blocking

(5) Easy workability and simple construction.

Military Specifications for general purpose crates are listed in Table 9-6. Refs. 5 and 6 contain detailed information on wooden boxes and their design. Specifications covering wooden and paper-overlaid veneer boxes commonly used are:

a. PPP-B-576, *Box, Wood, Cleated, Veneer, Paper Overlaid*

b. PPP-B-585, *Box, Wood, Wirebound*

c. PPP-B-601, *Box, Wood, Cleated-plywood*

TABLE 9-2
MECHANICAL PROPERTIES OF ALUMINUM ALLOYS

Property	Cast	Wrought
Tensile Strength, minimum psi	42,000	80,000
Yield Strength, minimum psi	22,000	72,000
Endurance Limit, minimum psi	13,500	24,000
Elongation, percent	6	varies markedly
Modulus of Elasticity, psi	9.9×10^6 to 11.4×10^6 (generally taken as 10.3×10^6)	

TABLE 9-3
MECHANICAL PROPERTY RANGES OF MAGNESIUM ALLOYS

Property	Cast	Wrought
Tensile Strength, psi	12,000 to 35,000	28,000 to 48,000
Yield Strength, psi	10,000 to 22,000	14,000 to 38,000
Fatigue Strength, psi	9,000 to 14,000	11,000 to 22,000
Elongation, %	2 to 7	2 to 12
Modulus of Elasticity, psi	Generally taken as 6.5×10^6	

TABLE 9-4
PHYSICAL PROPERTIES OF MAGNESIUM ALLOYS

Property	Range		Notes
	Casting Alloys	Wrought Alloys	
Specific Gravity	1.74 to 1.86	1.76 to 1.83	About 1/4 that of steel
Weight, lb/in^3	0.0628 to 0.0670	0.0633 to 0.0661	Approximately 112 lb/ft^3
Electrical Conductivity International Annealed Copper Standard) %	10.0 to 30.3	11.9 to 34.5	Values depend upon composition and temper of the alloys. Heat treatment of casting alloys generally tends to lower conductivity as compared with the as-cast condition. The lowest values appear in the -T4 temper for a given composition. The high value for wrought alloys appears in alloy M1A and the low value in AZ80A (both specified in QQ-M-31 and QQ-M-40).
Thermal Conductivity col/(sec)(cm^2)(°C/cm)	0.10 to 0.29	0.12 to 0.33	Appreciably lower than the values for corresponding aluminum-alloy materials.
Thermal Expansion means coefficient per degree F between the range of 20° to 100°C	26.1×10^{-6}	26.1×10^{-6}	In applications where magnesium alloys are rigidly connected to other material and the assembly is subject to appreciable variation in temperature, this relatively high coefficient must be given consideration.

TABLE 9-5
REQUIREMENTS FOR FIBERBOARD BOXES[8,9]

(1) Maximum Weight	(2) Maximum Dimensions	(3) Minimum Board Weight	(4) Minimum Bursting Test	
	Single-wall Corrugated Boxes			
20	40	52	125	
40	65	75	175	
65	75	84	200	
90	90	138	275	
120	100	180	350	
	Double-wall Corrugated Boxes			
65	75	92	200	
90	90	110	275	
120	100	126	350	
140	110	222	500	
160	120	270	600	
	Triple-wall Corrugated Boxes			
275	120	264	(5)	
	Solid Fiberboard Boxes			
20	40	114	125	
40	65	149	175	
65	75	190	200	
90	90	237	275	
120	100	283	350	
140	110	330	500	
160	120	360	600	
	Weather-resistant Fiberboard (6)		Dry	Wet
20	30	20	175	50
40	50	40	275	100
70	80	40	400	150
90	90	60	550	500
100	100	70	750	500

Notes:
(1) Maximum weight of box and contents, lb
(2) Maximum inside dimensions, length plus width plus depth, in.
(3) Minimum added total weight of the facings (flat sheets) including inner sheets but not the corrugated walls and not the adhesives, in the corrugated boxes, and, in the solid fiberboard boxes, the total weight of the component plies making up the board but not including the adhesives, in lb/1000 ft^2
(4) Minimum bursting test of the combined board in accordance with the prescribed method, in lb/in^2
(5) Puncture test to be used instead of bursting; minimum is to be 1100 units.
(6) Type 2 load.

d. PPP-B-621, *Box, Wood, Nailed and Lock Corner.*

Plywood drums are lightweight containers suitable for the shipment of dry products. They are tight and, because of the crossgrained construction, are rigid and do not tend to distort. Also, they are easily adaptable for reuse. Caution must be exercised in the reuse of drums for different commodities as this practice can result in contamination.

Properties of wood, plywood, and paper-overlaid veneer relevant to their use in container fabrication are categorized in Table 9-11.

9-2.4 PLASTICS

In general most plastics exhibit the highly desirable characteristics of light weight and a high strength-to-weight ratio. Other advantages of plastics are a high resistance to corrosion, fungus, and insects. The main disadvantage of plastic containers is that they are more expensive, at present, than metal or wooden containers of comparable use and quality. Other disadvantages are strength limitations at temperature extremes. At low temperatures, plastics become brittle. At high temperatures, they become soft. Temperature limitations can best be overcome by the selection of the proper plastic for the temperature conditions expected to be encountered by the container.

A factor not found in other container materials and to be considered in the use of plastics is the susceptibility to electrostatic charge buildup. The problems associated with electrostatic charge are explained in par. 8-1.5. The problems as explained relate to plastic film, but are also applicable to sheet plastic as used in containers.

The advantages and disadvantages of the different types of plastics from a structural point of view are shown in Table 9-8. Properties of plastics relevant to their use in container fabrication are provided in Table 9-12. Ref. 7 contains additional data on plastic materials.

Specifications covering some of the more commonly used plastics are:

a. *General*

(1) MIL-M-14, *Molding Plastics and Molded Plastic Parts, Thermosetting*
(2) MIL-P-8257, *Plastic Sheet, Thermosetting, Transparent*
(3) MIL-P-14591, *Plastic Film, Nonrigid, Transparent*
(4) L-P-505, *Plastic Sheet, Corrugated, Translucent, Glazing*
(5) *L-P-00517, Plastic Sheet, Scribecoated*

b. *Acrylic*

(1) MIL-P-5425, *Plastic Sheet, Acrylic, Heat Resistant*
(2) MIL-P-8184, *Plastic Sheet, Acrylic, Modified*
(3) MIL-P-21105, *Plastic Sheet, Acrylic, Heat Resistant, Utility Grade*
(4) MIL-P-25374, *Plastic Sheet, Acrylic, Modified, Laminated*
(5) MIL-P-25690, *Plastic, Sheets and Parts, Modified, Acrylic Base, Monolithic, Crack Propagation Resistant*
(6) L-P-391, *Plastic, Methacrylate, Sheets, Rods and Tubes–Cast*

c. *Acrylonitrile Butadiene Styrene (ABS)*

(1) MIL-P-19904, *Plastic Sheet, Acrylonitrile Butadiene Styrene Copolymer, Rigid*
(2) MIL-M-22544, *Molding Plastic, Acrylonitrile-Butadiene-Styrene, Rigid*

d. *Cellulose Acetate*

(1) MIL-P-21094, *Plastic Sheet, Cellulose Acetate Optical Quality*
(2) L-P-504, *Plastic Sheet and Film, Cellulose Acetate*

e. *Cellulose Acetate Butyrate*

(1) MIL-C-5537, *Cellulose Acetate Butyrate*
(2) L-P-349, *Plastic Compounds, Molding, Cellulose Acetate Butyrate, and Molded or Extruded Parts*

f. *Diallyl Phthalate (Allyl Resin)*

(1) MIL-R-21931, *Resin, Epoxy*

g. *Ethyl Cellulose*

(1) MIL-E-10853, *Ethyl Cellulose*

h. *Halogenated Hydrocarbons*

(1) MIL-P-19468, *Plastic Rods, Polytetrafluoroethylene, Molded and Extruded*
(2) MIL-M-21470, *Molding Plastics, Polychlorotrifluoroethylene*
(3) MIL-P-22241, *Plastic Film, Polytetrafluoroethylene (TFE-Fluorocarbon Resin)*
(4) MIL-P-46036, *Plastic Sheets, Rods, Tubes and Disks, Chlorotrifluoroethylene Polymer*

i. *Nylon (Polyamide)*

(1) MIL-N-18352, *Nylon Plastic, Flexible, Molded or Extruded*
(2) MIL-M-19098, *Molding Plastic, Polyamide*

TABLE 9-6
MILITARY SPECIFICATIONS FOR GENERAL PURPOSE CRATES

Specification	Maximums			
	Net Load, lb	Length, ft	Width, ft	Height, ft
MIL-C-104 (1)				
Sill Base	20,000	30	9	10
Skid Base	30,000	30	9	10
PPP-C-650 (2)				
Style A-I	250	4	3	3
A-II	500	12	4	2
A-IV	1,000	6	4	4
A-V	2,500	12	6	6
B-I	200	4	3	3
B-II	500	12	4	2
B-III (3)				
B-V	4,000	32	6	10
MIL-C-3774 (1)				
Nailed	12,000	16	8	8
Bolted	16,000	40	8	16

Notes:
(1) All dimensions overal, exterior
(2) All dimensions interior
(3) No load or size restrictions except as limited by handling methods.

TABLE 9-7
COMPARATIVE PRICES OF PLASTICS

Material	Ave Cost, $/lb
Polyethylene, Low Density	.13
Polystyrene, General Purpose	.15
Polyethylene, High Density	.17
Polystyrene, Medium High Impact	.23
Polypropylene	.24
Polyvinyl Chloride	.26
Amino Resin (Urea Filled)	.27
Vinyl, Rigid	.27
Phenolic, Filled	.31
Vinyl Acetate	.34
ABS Resins	.36
Amino Resin (Melamine)	.46
Cellulose Acetate	.46
Acrylic	.46
Alkyd	.56
Cellulose Acetate Butyrate	.62
Cellulose Propionate	.62
Acetal	.65
Ethyl Cellulose	.75
Polycarbonate	.80
Polyamide (Nylon 610)	1.20
Epoxy, Filled	1.30
Allyls	1.95
Silicone	3.45
Chlorinated Polyether	4.50
Fluorocarbon	5.90

Note: Costs are for comparison only and are subject to change. Some plastics vary considerably in cost with the particular densities and properties available. An average cost has been presented for these.

(Nylon), and Molded and Extruded Polyamide Plastic Parts–Weather Resistant

(3) MIL-M-20693, *Molding Plastic, Polyamide (Nylon) Rigid*

(4) MIL-P-22096, *Plastic, Polyamide (Nylon), Flexible Molding and Extrusion Material*

j. *Phenolics*

(1) MIL-R-3745, *Resin, Phenol-Formaldehyde, Laminating*

(2) MIL-R-9299, *Resin, Phenolic, Low Pressure Laminating*

(3) MIL-R-15184, *Resin, Para-Phenyl, Phenol-Formaldehyde*

(4) L-P-310, *Phenolic Molded Plastics*

(5) TT-R-271, *Resin Phenol-Formaldehyde, Para-Phenyl*

k. *Polyester (Alkyd)*

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS

Plastic	Advantages	Disadvantages
THERMOPLASTICS		
Acrylic	Formability; good impact strength; high index of refraction; good aging and weathering resistance; high transparency; shatter-resistance, rigidity.	Tendency to cold flow; softening point of 170° to 220°F; low scratch resistance.
Cellulose acetate	Ease of fabrication; moderate impact strength and toughness; good optical properties; good electrical properties; good resistance to gasoline and oil.	Loss of strength at 140° to 180°F; decomposition by strong acids and alkalies; high water absorption; low temperature brittleness; poor outdoor aging.
Cellulose acetate butyrate	Excellent molding properties; high impact strength and toughness; good dimensional stability and resilience; low moisture absorption.	Low flexural strength; low softening point (100° to 180°F;) suitable only for relatively low loads; poor thermal dimensional stability.
Cellulose nitrate	Ease of fabrication; relatively high impact strength and toughness; good dimensional stability and resilience; low moisture absorption.	Extreme flammability; very rapid degradation when exposed to sunlight; poor electrical insulating properties; harder with age; low heat distortion point.
Ethyl cellulose	Toughness at low and normal temperatures; high tensile and impact strengths; comparatively stable in high humidities.	Softening point of 110° to 200°F; poor resistance to attack by organic solvents; poor outdoor weathering resistance.
Polystyrene	Very low specific gravity; excellent moldability; dimensional stability; properties maintained over range of -40 to + 180°F; relative-	Extreme brittleness; softening point of 190°F; tendency to craze; attacked by aromatic solvents; poor weathering

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS (Cont.)

Plastic	Advantages	Disadvantages
THERMOPLASTICS (CONT'D)		
Polystyrene (cont'd)	ly high tensile, compressive, flexural strengths; high modulus of elasticity; exceptional electrical properties which remain constant over wide range of frequencies, temperatures and humidities, and after long immersion in water; fungi-inert; negligible water absorption; low cost.	resistance.
Modified polystyrene[1]	10° to 30°F improvement in heat distortion temperature over polystyrene; greater resistance to chemical and solvent attack; higher impact strength; complete water resistance.	Degrades excessively when stored at high temperatures or subjected to outdoor exposure.
Polyamide (nylon)	High resistance to distortion under load at temperatures up to 300°F; high tensile strength, excellent impact strength at normal temperatures;[2] does not become brittle at temperatures as low as -70°F; excellent resistance to gasoline and oil; low coefficient of friction on metals.	Absorption of water; large coefficient of expansion; high molding temperatures; relatively high cost; sensitive to ultraviolet light; weathering resistance poor.
Polyethylene	Inert to many solvents and corrosive chemicals; flexible and tough over wide temperature range, remains so at temperatures as low as -100°F; unusually low moisture absorption and permeability; high electrical	Low tensile, compressive, flexural strength; very high elongation at normal temperatures; subject to spontaneous cracking when stored in contact with alcohols, toluene, and silicone

Notes:

(1) Developed especially to overcome disadvantages of polystyrene.

(2) Tensile strength decreases with rising temperatures, elongation, and impact strength increases, as with all thermoplastics.

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS (Cont.)

Plastic	Advantages	Disadvantages
THERMOPLASTICS (CONT'D)		
Polyethylene (Cont'd)	resistivity; low dielectric constant and power factor; dimensionally stable at normal temperatures; will not support fungal growth; ease of molding; low density; low cost.	grease, etc.; softens at temperatures above 200°F poor abrasion and cut resistance; may be deteriorated by ultraviolet light unless properly compounded; cannot be bonded unless given special surface treatment.
Polytetrafluoroethylene	Extreme chemical inertness; high heat resistance; nonadhesive; tough; low dielectric loss over wide temperature range; low coefficient of friction.	Not easily cemented; cannot be molded by usual methods; generates toxic fumes at high temperatures; high cost.
Polytrifluorochloroethylene	Extreme chemical resistance; good electrical properties; high heat resistance; zero water absorption; good resistance to cold flow; stability over wide temperature range; good weathering qualities.	Limited elasticity; high cost; difficulty of cementing.
Vinyl chloride	Good tensile strength; good acid, solvent, caustic resistance; low water absorption; fair electrical properties.	Low softening point; adverse effect of sunlight; requires plasticizers.
Rigid polyvinyl chloride	Good weathering resistance; good resistance to most acids, alcohols, organic solvents; does not support combustion; high flexural strength; excellent toughness and ductility (even at -65°F); high impact strength.	Difficult to mold; subject to flow under load at 140° to 180°F.

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS (Cont.)

Plastic	Advantages	Disadvantages
THERMOPLASTICS (CONT'D)		
Vinylidene chloride	Exceptional chemical resistance; good aging resistance; good electrical properties; low moisture absorption; high strength.	Poor thermal stability; low thermal conductivity; adverse effect of sunlight.
Rigid vinylidene chloride	Good tensile, compressive, flexural strengths; low elongation; fair impact resistance; dimensionally stable at moderate loadings and temperatures; performs satisfactorily at moderately high temperatures.	Strength and physical stability reduced with rising temperatures; not recommended at over 170°F, or for uses involving resistance to highspeed impact, shock resistance, or flexibility at subfreezing temperatures.
THERMOSETTING PLASTICS		
Phenolformaldehyde	Used by U.S. Army for ordnance purposes in greater variety of end items and greater total tonnage than any other plastic; better permanence characteristics than most plastics; may be used at temperatures from 250° to 475°F; good aging resistance; good electrical insulating properties; not readily flammable, does not support combustion; inserts can be firmly embedded; strong, light; low water absorption; low thermal conductivity; good chemical resistance; economical in production of complex shapes; free from cold flow; relatively insensitive to tem-	Difficult to mold when filled for greatest impact strength, or when in sections less than 3/32-inch thick; can be expanded or contracted by unusually wet or dry atmosphere; poor tracking and arc resistance.

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS (Cont.)

Plastic	Advantages	Disadvantages
THERMOSETTING PLASTICS (CONT'D)		
Phenolformaldehyde (Cont'd)	perature; low coefficient of thermal expansion; no change in dimensions under a load for a long time; does not soften up to the degradation temperature or become brittle down to -65° F; inexpensive.	
Melamineformaldehyde	Good arc, track, organic solvent, and heat resistance (210° to 250°F); high impact strength with some fillers; rigid; hard surface withstands continuous handling and wear with negligible effect; flame resistant; low temperature resistant.	High power factor; high cost; dimensionally unstable with varying humidities.
Ureaformaldehyde	High degree of translucency and light finish; hard surface finish; outstanding electrical properties when used within temperature range of -70° to +170°F; complete resistance to organic solvents; dimensionally stable under moderate loadings and exposure conditions.	Low impact strength; slight warping with age; poor water resistance.
Allyl	Good clarity; freedom from optical creep; good resistance to chemicals, abrasion, crazing, and deformation under heat; rigid and dimensionally stable at moderate temperatures and loadings.	Low impact strength; high shrinkage; care required in machining and handling; physical properties reduced at elevated temperatures.

TABLE 9-8
ADVANTAGES AND DISADVANTAGES OF PLASTICS (Cont.)

Plastic	Advantages	Disadvantages
THERMOSETTING PLASTICS (CONT'D)		
Alkyd	Excellent electrical properties; heat distortion temperatures of 350° to 400°F, 300° to 350°F for continuous service; reinforced compounds have high impact strength dimensional stability, and yield strength; good flow properties.	Poor resistance to strong acids; require fast-closing molds; high specific gravity.
Epoxy resin	Excellent chemical resistance; excellent adhesion to metals, glass, ceramics; good mechanical and electrical properties; retains electrical properties under severe temperature and humidity; castings can be cycled from -60° to + 400°F without cracking.	Relatively high cost; relatively poor heat resistance (compared to polyesters and phenolics).
Silicones	High heat resistance; do not support combustion; low water absorption; good electrical properties over a wide frequency range; electrically nontracking.	Require a special molding and curing techniques; relatively expensive.
Polyester resins	Very high strength in the form of glass reinforced laminates; excellent electrical properties; can be molded in very large sections under low pressure in in-expensive molds; good heat resistance; good resistance to chemicals, gasoline and oil; excellent low temperature properties; good weathering resistance.	Excessive (4 to 8 percent) shrinkage on molding; only fair adhesion.

(1) MIL-R-7575, *Resin, Polyester, Low Pressure Laminating*
(2) MIL-R-21607, *Resin, Polyester, Low Pressure Laminating, Fire Resistant*
(3) MIL-R-25042, *Resin, Polyester, High Temperature Resistant, Low Pressure Laminating*

l. *Polyethylene*
(1) MIL-P-21922, *Plastic Rods and Tubes, Polyethylene*
(2) MIL-P-55010, *Plastic Sheet, Polyethylene, Terephthalate*
(3) MIL-P-55011, *Plastic Sheet, Polyethylene, Terephthalate, Translucent, Scribecoated*
(4) L-P-378, *Plastic Film (Polyethylene, Thin Gage)*

m. *Polyvinyl Alcohol*
(1) MIL-P-265, *Polyvinyl Alcohol, Granular*

n. *Polyvinyl Chloride*
(1) MIL-P-20307, *Polyvinyl Chloride*
(2) L-M-530, *Molding Plastic, Polyvinyl Chloride, Rigid*
(3) L-P-501, *Plastic, Polyvinylidene Chloride (Saran, Molded)*
(4) L-P-503, *Plastic Rod, Solid, Polyvinyl Chloride, Rigid*
(5) L-P-510, *Plastic Sheet, Polyvinyl Chloride, Rigid*
(6) L-P-540, *Plastic Tube and Tubing, Heavy Walled, Polyvinyl Chloride, Rigid*

o. *Silicone*
(1) MIL-R-25506, *Resin, Silicone, Low Pressure Laminating, Urea*
(2) L-P-401, *Plastic Molding Material Urea Formaldehyde*
(3) L-U-671, *Urea Molded Plastics*

p. *Vinyl Chloride and Copolymers*
(1) MIL-P-6264, *Plastic Sheet, Vinyl Copolymer, Thin*
(2) MIL-P-18080, *Plastic Sheets, Vinyl, Flexible, Transparent, Optical Quality*
(3) L-P-375, *Plastic Film, Flexible, Vinyl Chloride.*

9-2.5 REINFORCED PLASTICS

Reinforced plastics are used for sheathing or for structural members of containers. They are a combination of a plastic and a reinforcing material embedded in or saturated with the plastic.

The properties of reinforced plastics depend upon the materials combined, the relative amounts of the materials used, and the manner in which the combination is formed. The properties of some common reinforced plastics are shown in Table 9-13.

9-3 CONTAINER MATERIALS SELECTION CHARTS

The physical properties and characteristics of the various container materials are presented in Tables 9-9 through 9-13. The information given in these tables will aid in the selection of a material capable of meeting the physical requirements of a particular application. It should be noted that factors other than physical characteristics are important in selecting a container material and the data listed in Tables 9-9 through 9-13 must be evaluated with these other factors in mind.

Important physical characteristics of container materials include specific gravity; tensile strength; compressive strength; ratios of tensile and compressive strength to specific gravity; modulus of elasticity; resistance to impact, abrasion, and puncture; and reported hazards to stability. The identification of material given in the first column of Tables 9-9 through 9-13 is the commercial identification of the material. In some instances the ultimate tensile strength is not shown, but yield strength is given and indicated by the prefix Y. Yield strength is defined as "the lowest tensile force at which elongation continues without an increase in force divided by the minimum cross-sectional area of the specimen before a load is applied". Ratios of tensile and compressive strength are useful in comparing the weights required for a particular strength. The modulus of elasticity determines the ability of a material to resist deflection under loads.

Impact resistance is measured by a variety of test methods and, even within one group of similar materials, more than one method is used. The test method is given by a footnote for the material or group of materials, and the energy required to fail the material is given in the table. Comparisons of impact resistance determined by different methods are not valid, even though energy units are the same.

Abrasion resistance is not used in design and is rarely the cause of container failure. The information is useful, however, in the selection of parts subject to wear, such as rubbing strips and skids.

Puncture resistance is measured by a variety of tests, depending on the form of the material.

Hardness is a measure of the resistance of the material to the penetration of a point or other indenter.

The hardness of different materials may be compared if the same indenter is used, but when different indenters are used the data must be converted to a common scale.

Listed in Tables 9-10 through 9-13, under the column "Reported Hazards to Stability", are code letters for the hazards of environment that cause a 10 percent reduction in any one of the characteristics. The definitions of the code letters are:

a - Temperature extremes, −65° or +160°F

b - Submersion in water for 24 hr

c - Submersion in oil for 24 hr

d - Organic solvents

e - Acids

f - Salts or salt solutions

g - Bacteria and fungi

h - High humidity

i - Low humidity

j - Sunlight

k - Chemical bases

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TABLE 9-9
CONTAINER MATERIAL SELECTION CHART-METALS

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{\text{Sp gr}}\right)$, psi	Compressive strength F_c,[1] psi	Ratio $\left(\frac{10^{-3} F_c^{(1)}}{\text{Sp gr}}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture
Steels, Wrought[2]									
High carbon C1095, hot rolled	7.85	142,000	18.1	Y 84,000	Y 10.7	30.0	3	--	293
C1095, annealed	7.85	100,000	12.7	Y 53,000	Y 6.75	30.0	5		197
C1055, C1060, hot rolled	7.85	110,000	14.0	Y 51,500	Y 6.56	30.0	15		240
C1055, C1060, annealed	7.85	100,000	12.7			30.0	20		190
Medium C1040, C1045, hot rolled	7.85	95,000		Y 42,000	Y 5.35	30.0	--		205
C1040, C1045, annealed	7.85	100,000	12.7			30.0	--		210
C1030, C1035, hot rolled	7.85	80,000		Y 37,500	Y 4.77	30.0	--		170
Low carbon C1018, hot rolled	7.85	69,000	8.79	Y 32,000	Y 4.08	30.0			143
C1015, C1010, hot rolled	7.85	51,000	6.50	Y 26,000	Y 3.31	30.0			101
C1020, C1025, hot rolled	7.85	65,000	8.28	Y 30,000	Y 3.82	30.0			143
Low alloy, high strength (hardened and tempered)									
Alloy No. 4023	7.8	120,000	15.4	Y 85,000	Y 10.9	30.0	--		255
Alloy No. 4063	7.8	269,000	34.5	Y 231,000	Y 29.6	30.0			534
Alloy No. 4130	7.8	200,000	25.6	Y 170,000	Y 21.8	30.0	25		375
Alloy No. 4150	7.8	230,000	29.5	Y 215,000	Y 27.5	30.0	12		444
Alloy No. 6150	7.8	187,000	24.0	Y 179,000	Y 22.8	30.0	13		444
Steels, stainless									
Austenitic No. 201, annealed	7.85	115,000	14.6	Y 55,000	Y 7.00	28.6			B90
Austenitic No. 301, annealed	7.9	110,000	13.9	Y 40,000	Y 5.06	28.0	165		B85
Austenitic No. 304, annealed	7.9	85,000	10.8	Y 35,000	Y 4.43	28.0	110		B80
Austenitic No. 201 and 301 full hard	7.9	185,000	23.4	Y 140,000	Y 17.7	28.0			
Aluminum Alloys, Wrought[3]									
7178-T6	2.8	88,000	31.4	Y 78,000	Y 27.9	10.4			
Alclad 7178-T6	2.8	81,000	28.9	Y 71,000	Y 25.4	10.4			
7075-T6	2.8	83,000	29.6	Y 73,000	Y 26.1	10.4			B90
Alclad 7075-T6	2.8	76,000	27.1	Y 67,000	Y 23.9	10.4			B100
Alclad 2024-T86	2.8	70,000	25.0	Y 66,000	Y 23.6	10.6			
Magnesium Alloys, Wrought[4]									
AZ31B - H24	1.78	39,000	21.9	Y 29,000	Y 16.3	6.5	32		B83
ZE10A - H24	1.78	36,000	20.2	Y 25,000	Y 14.0	6.5			
ZK60 A and B - T5	1.83	50,000	28.1	Y 40,000	Y 22.5	6.5			B88

Notes:

(1) The prefix "Y" before an entry identifies it as yield strength.

(2) Steels: the resistance to impact is given in foot-pounds as determined by the notched Izod test, and the resistance to puncture is the hardness number as determined by either the Brinell test (no prefix given) or the Rockwell test (scale prefix letter is given).

(3) Aluminum alloys: the resistance to puncture was the hardness number as determined by the Rockwell test.

(4) Magnesium alloys: the resistance to impact is given in foot-pounds as determined by the Charpy test, and the resistance to puncture is the hardness number determined by the Rockwell test.

TABLE 9-10
CONTAINER MATERIAL SELECTION CHART–FIBERBOARDS

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{\text{Sp gr}}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{\text{Sp gr}}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Corrugated Fiberboard[1]										
(Double-faced, 125-lb, Mullen)										
A-flute	0.096			120	1.25				140	
B-flute	0.156			210	1.34				126	
C-flute	0.119			160	1.34				133	
(Double-faced, 350-lb. Mullen)										
A-flute	0.194			310	1.60				375	
B-flute	0.271			490	1.80				375	
C-flute	0.234			380	1.62				356	
(Double-wall, 200-lb. Mullen)										
A- and B-flutes	0.113			200	1.77				250	
A- and C-flutes	0.100			180	1.80				262	abdegh
B- and B-flutes	0.151			280	1.85				225	
B- and C-flutes	0.130			230	1.77				237	
C- and C-flutes	0.113			200	1.77				250	
(Double-wall, 600-lb. Mullen)										
A- and B-flutes	0.198			290	1.46				700	
A- and C-flutes	0.179			260	1.45				735	
B- and B-flutes	0.256			380	1.48				630	
B- and C-flutes	0.224			330	1.47				665	
C- and C-flutes	0.198			290	1.46				700	
(Triple-wall board)										
A-C-A-flutes	0.135			230	1.70				1100	
Solid Fiberboard[1]										
Domestic (low values)	0.54			910	1.44					
(high values)	0.65			1,250	2.07					abdegh
VUS	0.72			1,170	1.62					
V2s	0.74			1,200	1.62					
V3a	0.67			1,080	1.61					
W5s	--			1,350	--					
Fibrous Felted Boards[2]										
Superhard board	1.36	7800	5.74	26,500	18.4					
Superhard board	1.44	7800	5.42	26,500	19.5					
Tempered hardboard	0.96	4000	4.17	4,200	4.37					
Tempered hardboard	1.28	7800	6.10	6,000	4.69					abdegh
Untempered hardboard	0.8	3000	3.75	1,800	2.25					
Untempered hardboard	1.28	6000	4.69	6,000	4.69					
Medium density board	0.42	800	1.91	500	1.18					
Medium density board	0.8	2000	2.50	3,400	4.25					
Structural insulating board	0.16	200	1.25	--	--					
Structural insulating board	0.42	500	1.19	--	--					

Notes:

(1) Corrugated and solid fiberboard: the resistance to puncture is given in inch-pounds as determined by ASTM Test Method designation, and the compressive strength is determined by the short column test method.

(2) Fibrous felted properties from various sources and test methods are not identified.

(3) Refer to par. 9-3 for the code letter breakdown.

TABLE 9-11
CONTAINER MATERIAL SELECTION CHART–WOOD, PLYWOOD, AND PAPER OVERLAID VENEER

Material	Specific gravity (Sp gr)	Tensile Strength F_t M of R, psi	Ratio $\left(\frac{10^{-3} F_t}{\text{Sp gr}}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{\text{Sp gr}}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to			Reported hazards to stability (3)
							Impact	Abrasion	Puncture	
Wood, Clear and Straight Grain[1]										
(Group I container woods)										
Aspen (popple)	0.35	5100	14.6	2140	6.1	0.95	22		300	adegi
Basswood	0.32	5000	15.6	2220	6.9	1.14	16		250	adeg
Buckeye	0.33	4800	14.5	2050	6.2	1.08	18		290	adegi
Cedar, northern white	0.29	4200	14.5	1990	6.9	0.70	15		230	adegi
Cedar, Alaska	0.42	6400	15.2	3050	7.3	1.25	27		440	adeg
Chestnut	0.40	5600	14.0	2470	6.2	1.02	24		420	adegi
Cottonwood	0.37	5300	14.3	2280	6.2	1.11	21		340	adeg
Cypress (baldcypress)	0.42	6600	15.7	3580	8.5	1.30	25	0.056	390	adeg
True firs, balsam	0.34	4900	14.4	2400	7.1	1.06	16		290	adeg
True firs, grand	0.37	6100	16.5	3020	8.2	1.43	22		360	adeg
Magnolia	0.46	6800	14.8	2700	5.9	1.22	54		740	adegi
Pines, sugar	0.35	5100	14.6	2530	7.2	1.03	17	0.148	310	adeg
Pines, Virginia	0.45	7300	16.0	3420	7.6	1.30	21		540	adeg
Redwood	0.38	7500	19.7	4200	11.0	1.30	21	0.154	410	adeg
Spruces, Engelmann	0.32	4500	14.1	2190	6.8	1.06	16	0.040	260	adeg
Spruces, red	0.38	5800	15.3	2650	7.0	1.31	18		350	adeg
Willow, black	0.34	3800	11.2	1520	4.5	0.62	36		430	adegi
Yellow-poplar	0.40	6000	15.0	2660	6.7	1.34	26	0.060	440	adeg
(Group II container woods)										
Douglas-fir	0.40	6400	16.0	3000	7.5	1.30	20	0.038	450	adeg
Hemlock	0.38	6100	16.0	2990	7.9	1.34	22		430	adeg
Southern yellow pine, loblolly	0.47	7300	15.5	3490	7.4	1.54	30		450	adeg
Southern yellow pines, longleaf	0.54	8700	16.1	4300	8.0	1.76	35	0.027	590	adeg
Tamarack	0.49	7200	14.7	3480	7.1	1.36	28		380	adegi
Western larch	0.51	8200	16.1	3990	7.8	1.68	29		510	adeg
(Group III container woods)										
Ash, black	0.45	6000	13.3	2300	5.1	1.14	33		520	adeg
Ash, green	0.53	9500	17.9	4200	7.9	1.54	35		870	adeg
Soft elm	0.46	7200	15.6	2900	6.3	1.22	38		620	adeg
Soft maple	0.44	5800	13.2	2490	5.7	1.03	29		590	adegi
Sweetgum	0.46	7100	15.4	3040	6.6	1.32	36		600	adegi
Sycamore	0.46	6500	14.1	2920	6.3	1.17	26		610	adeg
Tupelo	0.46	7000	15.2	3040	6.6	1.13	30		640	adegi
(Group IV container woods)										
Beech	0.56	8600	15.4	3550	6.3	1.52	43	0.027	850	adeg
Birch (except paper birch)	0.55	8300	15.1	3380	6.1	1.65	48	0.023	810	adeg
Hackberry	0.49	6500	13.3	2650	5.4	1.05	48		700	adegi
Hard maple	0.52	7900	15.2	3270	6.3	1.46	48	0.012	840	adegi
Hickory, shellback	0.62	10,500	16.9	3920	6.3	1.47	74			adegi
Hickory, pignut	0.66	11,700	17.7	4810	7.3	1.82	89	0.009		adegi
Oak, southern red	0.52	6900	13.3	3030	5.8	1.25	29		860	adegi
Oak, swamp white	0.64	9900	15.5	4360	6.8	1.75	50	0.018	1160	adeg
Pecan	0.60	9800	16.3	3990	6.6	1.51	53		1310	adegi
Rock elm	0.57	9500	16.7	3780	6.6	1.31	54		940	adeg
White elm	0.55	9600	17.5	3990	7.3	1.61	38	0.018	960	adeg
Plywood[2]										
(Container grade NN-P-530)										
Three-ply, group I, 3/16 inch	0.416	6620 1280	15.9 3.1						250	abdegh
3/20 inch	0.403	5820	14.4						175	abdegh
Paper-Overlaid Veneer[2]										
1/8 in. sweetgum (undried) with 0.016 in. kraft overlay	0.532	8070 1900	15.2 3.6						328	abdeghi
1/8 in. red oak (undried) with 0.016 in. kraft overlay	0.622	8170 1420	13.1 2.3						240	abdeghi
1/8 in. Douglas-fir (dry-distended) with 0.016 in. kraft overlay	0.467	7410 520	15.9 1.1						208	abdegh
1/12 in. birch (dried) with 0.027 in. asphalt-impregnated kraft overlay	0.770	8760 2380	11.4 3.1						280	abdegh
1/12 in. basswood (dried) with 0.027 in. asphalt-impregnated kraft overlays	0.617	5050 2090	8.2 3.4						155	abdegh
1/16 in. birch (dried) with two sheets 0.030 in. in sulfate cylinder kraft each face	0.666	3000 3420	4.5 5.1						371	abdegh

TABLE 9-11
CONTAINER MATERIAL SELECTION CHART–WOOD, PLYWOOD, AND PAPER OVERLAID VENEER (Cont.)

Notes:

(1) Wood: the strengths, elasticity impact resistance and puncture resistance were determined by ASTM Test Method D 143; impact resistance was expressed as the maximum height in inches from which a 50-pound weight was dropped to cause complete rupture in bending of a 2- x 2-inch specimen on a 28-inch span; the puncture resistance, or hardness, was the force required to embed a 0.44-inch-diameter steel ball to a depth of 0. 22 inch; and resistance to abrasion was expressed in inches removed per 1000 revolutions as measured on the U. S. Navy Wear-Test machine.

(2) Plywood and paper-overlaid veneer: the resistance to puncture was given in inch-pounds as determined by ASTM Test Method D-781, and tensile strength was measured by ASTM Test Method D 805.

(3) Refer to par. 9-3 for the code letter breakdown.

(4) M of R = modulus of rupture

TABLE 9-12
CONTAINER MATERIAL SELECTION CHART–PLASTICS

Material	Specific gravity (Sp gr)	Tensile Strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (2)
Plastics(1)										
Acetal	1.42	10,000	7.04	18,000	12.67	0.41	1.4	20.	R 120	aejk
Acrylic	1.18	Y14,000	Y11.86	17,000	14.40	0.40	0.3		M 88	
	1.19	9000	7.56	15,000	12.60	0.35	0.4		M 102	
	1.19	8000	6.72	12,000	10.08	0.35	0.4		M 84	
Acrylonitrile butadiene styrene (ABS)	1.07	7000	6.54			0.34	4.5		R 107	
	1.02	4000	3.92			0.21	6.5		R 83	
	1.07	4000	3.74	5500	5.14	0.20	5.0		D 76S	
	1.00	2000	2.00				6.5		D 60S	
Cellulose acetate	1.32	12,000	9.10							abdehik
	1.26	7000	5.56							
	1.34	6000	4.48	7200	5.37		0.4		R 112	
	1.33	5000	3.76	5000	3.76		0.8		R 101	
	1.34	2000	1.49	2100	1.566		2.0		R 52	
Cellulose acetate butyrate	1.25	6000	4.80	6500	5.20		0.6		R 114	
	1.18	2000	1.70	1100	0.932		3.2		R 59	
Cellulose acetate propionate	1.24	5000	4.03			0.14	0.8		R 100	
	1.19	1000	0.84			0.05	9.0		R 20	
Diallyl phthalate (allyl resin)	1.60	7000	4.38	25,000	15.6		0.5			
	1.40	4000	2.86	25,000	17.8		1.7			
	1.65	4000	2.42	20,000	12.1		0.2		M 99	
	1.31	4500	3.43	20,000	15.3	0.60	0.55			
Epoxy resin	1.15	9500	8.26	40,000	34.8	0.3	0.20		M 110	
	1.12	7000	6.25	30,000	26.79	0.3	0.43		M 90	
	1.00	100	0.10	3000	3.00	0.2	7.00			
Ethyl cellulose	1.16	6000	5.18			0.15	1.8		R 110	
	1.16	4000	3.45			0.10	3.5		R 80	
	1.16	3000	2.58				4.0		R 70	
Halogenated hydrocarbons	2.10	4000	1.90	12,000	5.72	0.01			R 112	
	2.30	1000	0.43			0.03	2.5		J 75	
Melamine formaldehyde	1.53	8000	5.23	30,000	19.60	1.6	0.5		M 119	
	1.53	7000	4.57	40,000	26.13	1.3	0.2		M 118	
	1.46	5000	3.42	9000	6.16		0.3			
	2.00	6000	3.00				4.0			
Nylon (polyamide)	1.14	8000	7.02	13,000	11.4	0.40	1.0	5.	R 118	adefhk
	1.09	6000	5.50	7200	6.60		1.0		R 111	
Phenolic	1.41	7000	4.96	30,000	21.3	1.4	0.48			adeg
	1.36	6000	4.41	25,000	18.37	1.2	0.28			
	1.74	6000	3.45	15,000	8.62		2.0		M 110	
	1.75	5500	3.14	25,000	14.28	2.6	0.30			
	1.35	3000	2.22	15,000	11.11	0.40	0.30		M 50	
	2.00	4000	2.00	15,000	7.50	3.0	0.30		M 100	
Polycarbonate	1.2	10,500	8.8	11,000	9.16	0.32	16.			
	1.2	9000	7.5				12.			
Polyester (alkyd)	2.08	6000	2.88	24,000	11.53	2.2	8.0		70 Bhn	
	1.90	4000	2.10	21,000	11.05	1.8	0.3		58 Bhn	
	2.28	3000	2.28	16,000	7.02	2.2	0.3		60 Bhn	
Polyethylene	0.96	4800	5.0			0.15	3.0		R 41	ade
	0.96	4000	4.17			0.08			R 30	
	0.91	1100	1.21							
Polypropylene	0.9	5000	5.56			0.14	0.8			ade
	0.9	4500	5.0			0.20	0.9			
Polystyrene	1.06	7700	7.2	13,000	12.26	0.44	0.5			
	1.06	5500	5.2	14,130	13.32	0.44	0.42		M 70	
	1.05	3740	3.53	9000	8.57	0.35	2.2			
	1.10	3000	2.73	3500	3.18	0.25	1.5		M 15	
Polyvinyl chloride	1.44	8950	6.22	9600	6.66	0.41	3.0		D 80S	abcdef
	1.30	5600	4.31	6500	5.00		0.4		D 76S	
Silicone	2.0	5000	2.50	13,000	6.50		3.0			
	2.0	4000	1.50	12,000	6.00		0.3			
	2.0	3000	1.50	16,000	8.00		0.2		M 85	
Urea formaldehyde	1.55	6000	3.87	30,000	19.35	1.3	0.2		E 94	
	1.50	5500	3.67	30,000	20.00	1.3	0.26		E 94	
Vinyl chloride acetate	1.35	7000	5.18				0.2			
	1.40	5000	3.57				0.3			
	1.40	4000	2.86				0.3			
Vinylidene chloride	1.75	3000	1.71			0.05	0.5		M 50	

Note:

(1) Plastics: resistance to impact is in foot-pounds per inch determined by the Izod test of 1/2-in notched bar specimens; resistance to puncture is the Rockwell hardness number except when either the suffix "Bhn" is used to indicate a Brinell hardness number or the suffix "S" is used to indicate a Shore hardness; and abrasion resistance is the percent of light diffused as measured by ASTM Test Method D 1044. Tensile strength and elasticity were determined by ASTM Test Method D-638 and compressive strength by ASTM Test Method D-695. Prefix letters in "puncture column" indicate Rockwell test scale.

(2) See par. 9-3 for the code letter breakdown.

TABLE 9-13
CONTAINER MATERIAL SELECTION CHART–REINFORCED PLASTICS

Material	Specific gravity (Sp gr)	Tensile Strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{\text{Sp gr}}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{\text{Sp gr}}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture	Reported hazards to stability
Reinforced Plastics[1]--Average Results of Tests of Specimens in Wet Condition										
Epoxy and glass 143	1.91			68,700	36.0	5.39			70	
				30,900	16.2	2.13				
Epoxy and glass 120	1.81			56,500	31.2	3.35			71	
				50,700	28.0	3.11				
Epoxy and glass 181	1.82			45,060	24.8	3.59				
				43,770	24.1	3.38				
Epoxy and glass 112	1.74			51,200	29.4	3.23			70	
				49,700	28.6	3.03				
Phenolic and cotton fabric	1.36	9530	7.0	15,650	11.5	0.78			46	
		9940	7.4	14,700	10.8	0.77				
Phenolic and glass fabric 181	1.82	43,850	24.1	31,650	17.4	3.20			59	
		42,530	23.4	28,510	15.7	3.06				
Polyester and glass 143	1.85	73,200	39.6	32,990	17.8	4.87			69	
		9120	4.9	14,130	7.5	0.98				
Polyester and glass 120	1.73	41,600	24.1	24,540	14.2	2.60			71	
		38,470	22.2	20,440	11.8	2.39				
Polyester and glass 181	1.80	39,370	21.9	24,240	13.5	2.53			73	
		38,790	21.5	22,340	12.4	2.69				
Polyester and glass 112	1.70	31,900	18.8	28,360	16.7	2.47			69	
		30,190	17.8	21,860	12.9	2.34				
Polyester and glass 116	1.82	36,850	20.3	16,660	9.2	2.82			68	
		33,180	18.2	13,960	7.7	2.56				
Polyester and glass 182	1.83	45,200	24.7	21,870	12.0	2.92			67	
		41,510	22.7	19,670	10.8	2.76				
Polyester and glass mat 503	1.69	22,920	13.6	11,340	6.7	1.54			62	
		23,340	13.8	12,250	7.2	1.61				
Silicone and glass 181	1.81			19,970	11.0	2.560			59	
				16,840	9.3	2.590				

Note:
(1) Reinforced plastics: puncture resistance was the Barcol hardness number. Tensile strength was measured by ASTM Test Method D-638, and the compressive strength and stiffness were measured by ASTM Test Method D-695.

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MIL-C-3774, *Crates, Wood, Open, 12000 and 16000 Pound Capacity.*

MIL-STD-731, *Quality of Wood Members for Containers and Pallets.*

MIL-HDBK-7, *Lumber and Allied Products.*

CHAPTER 10

EXTERIOR PROTECTION AND CONTAINERS

Having been packaged, items are shipped to destinations which, at the time of packaging, were unknown. Some of these items will be issued to organizations or delivered to depots within the continental limits of the U.S., and the remaining items will be shipped to oversea areas. The oversea areas represent the climatic spectra–the tropical jungles, the arctic regions, and the various islands of the seas. These areas support climatic conditions which include cold, heat, humidity, aridity, and the extreme temperature changes of the various regions. All of these possibilities must be taken into consideration when the container is initially designed. The container must assure adequate protection from the time of packing, through to the delivery, and after arrival to the using agency where the possibility of being subjected to adverse field conditions exist.

10-1 CONTAINER FUNCTIONS

A shipping container is any exterior bag or sack, box, can or drum, crate, etc., which is required to enclose one or more items during storage or shipment. The primary design consideration of an exterior container is the protection of the contents while providing for the ease of handling. A container will assist in the handling of an item which is normally difficult to handle and by consolidating a number of items into a single unit. The extent of protection provided by a container is dependent upon the contents, the type of container, the materials used in its construction, its assembly features, its final destination, and the anticipated hazards.

10-2 EXTERIOR CONTAINERS

The term "container" may be correctly applied to a wide variety of objects ranging from tiny paper envelopes to steel drums, huge wooden crates, and CONEX containers. Containers selected should be durable and consistent with logistic flow and environmental conditions. The minimum number of different containers necessary to house the complete item should be used, provided it is consistent with logistic flow and safety regulations. The same basic design should be used for containers holding similar items with similar requirements. When possible, uniformity in basic configuration, construction, and arrangement of auxiliary features should be designed into containers. Although adequate protection of the item is the controlling factor in selecting containers, all the factors illustrated in Fig. 10-1 may become critical for particular items.

10-2.1 ITEM CHARACTERISTICS

In selecting containers, the packaging engineer will need answers to the following questions concerning the item:

a. Is it extremely fragile?

b. Is it made of hazardous material?

c. Is there a need for its use in minimum reaction time?

d. Is it repairable or recoverable?

e. Does it have a high dollar value?

f. Is a high reliability required?

g. What is its tactical essentiality?

h. What is the logistic pattern?

i. What is the cost of an alternative?

The physical characteristics of size, fragility level, weight, and weight distribution of an item determine, to a large extent, the container size, type, and cost. The item weight may influence the size of the container structural members, type and capacity of shock and vibration systems, and in turn, transportation costs, and the manual and mechanical handling requirements.

The item weight distribution will affect the overall size of the container, the design and location of strength members such as reinforcing ribs, and the design of the shock and vibration isolation systems.

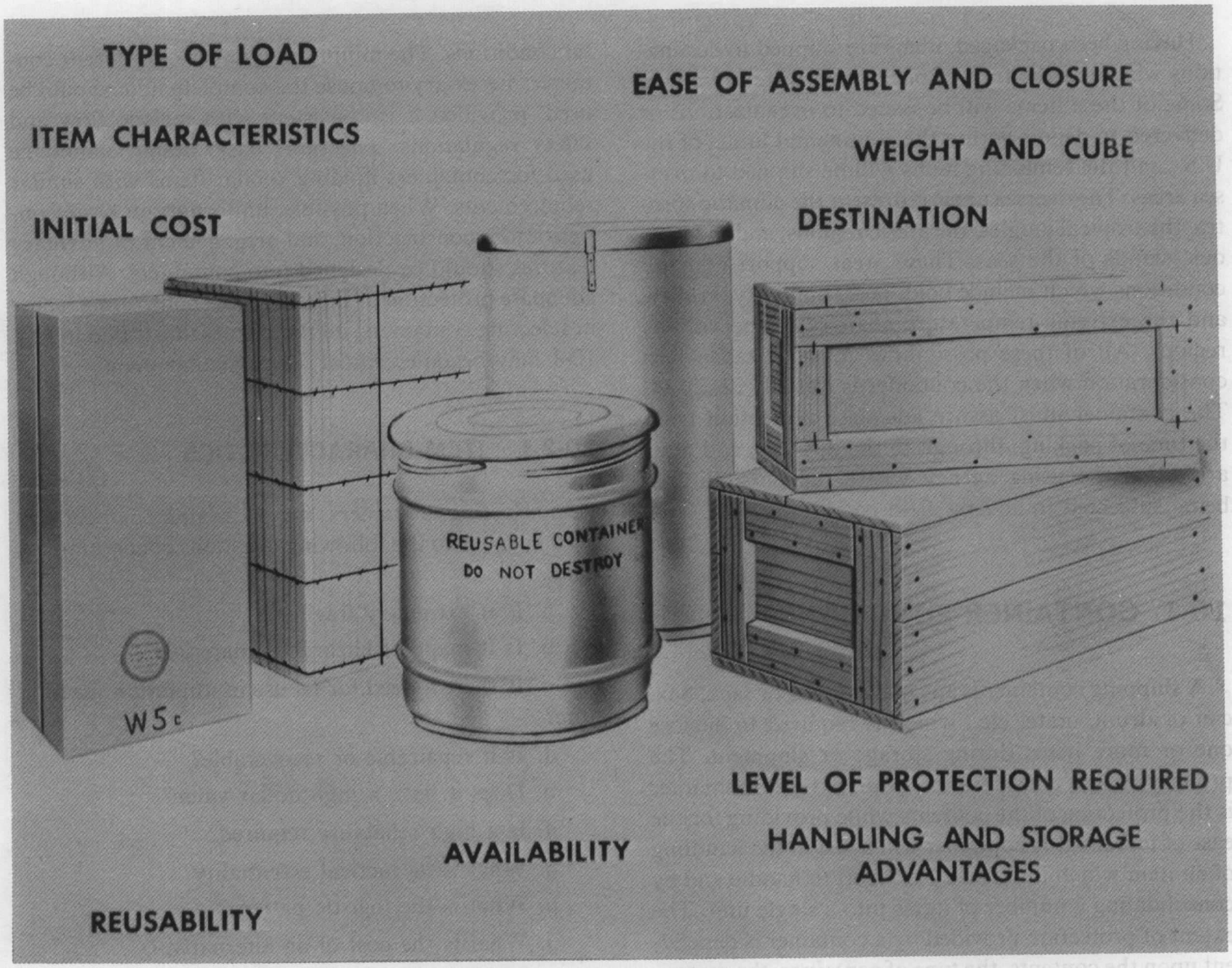

Fig. 10-1. Container Selection Factors

10-2.2 TYPE OF LOAD

The type of load, or the ability of an item to add strength to or cause damage to the faces of the container, is important in determining container selection. Internal and external forces developed during transit vary greatly for different loads. (Figs. 10-2(A), (B), and (C) illustrate packing for various types of loads.) If a container is not subjected to appreciable loads, it can be thin and light, but structural strength is required to resist loads imposed during handling, stacking, and shipping operations. Besides the force of the item on the container during shipment, pressures of shipping bands drawn tightly over the load and the additional dynamic loads caused by transportational vibration and shock must be considered. After taking into account all these loads, containers must then be selected which will not be dented or crushed, i.e., result in damage to the packaged item.

10-2.3 INITIAL COST OF CONTAINER

Initial costs include those that accrue in preparing for the first shipment, such as the cost of materials and the cost of labor. To keep costs to a minimum, standard parts, materials, and processes should be used to the maximum extent possible. Container design should require mechanical finishes and tolerances no more stringent than necessary to insure reliable operations throughout testing, storage, and operating life of the equipment. Containers chosen should be efficient and economical to fabricate, efficient to assemble, and made with minimum requirements for strategic materials, manpower, and plant facilities.

10-2.4 EASE OF ASSEMBLY AND CLOSURE

Advantage of quick opening is closely related to the cost of the container. Reaction time is a prime consideration for some items. In those cases, containers should have closures and fasteners that result in minimum packing and unpacking times commensurate with security of packaged items. Large containers, especially, should provide ready access to the mounting supports, and permit installation and removal of contents by means of a sequence of easy operations, using authorized lifting devices and tools. Fig. 10-3 illustrates types of quick-acting fasteners.

For items that do not require reaction time, more simple and economical fasteners are usually employed.

10-2.5 AVAILABILITY OF MATERIALS

Containers should be made by fabricating processes appropriate to the number of pieces required in a normal procurement request. Fabricating processes, if possible, should be readily available from several commercial sources that use mass production techniques. Selection should be confined, in most cases, to containers that are stocked at major supply points. Current regulations should be referred to for guidance in the conservation of strategic and critical materials associated with the design and production of military items.

10-2.6 EASE IN HANDLING AND STORAGE

All military containers must withstand handling and storage without impairment of the item by the effects of extreme conditions. For ease in storage, containers should be stable, strong, and capable of stacking and nesting on authorized pallets. All containers should have a minimum of protrusions such as closures, humidity indicators, handles, and valves. Also, any container that must be pushed, dragged, or handled by mechanical equipment should be provided with skids that allow ample clearance from ground level to permit removal by fork lift. Refs. 2, 13, and 14 contain instructions pertinent to general supplies.

10-2.7 DEGREE OF PROTECTION REQUIRED

The degree of protection required from the container will depend on the ultimate destination of the shipping container, the nature of the item or contents, and the known hazards. Depending on the protection required for an item, containers may use free-breathing design, pressurization, or desiccants. Fig. 10-4, for example, shows different methods of protecting the item through container design.

Consideration should also be given to the use of water- and fungus-resistant materials, protective coatings on metal containers and on large wooden containers, and the use of suitable preservative treatments on wooden members. Although protection is aimed at the item, not the container, in many cases, container deterioration may result in an attendant decrease in item protection.

10-2.8 REUSABILITY

The following four factors concerning the item will determine whether or not a reusable container will be selected:

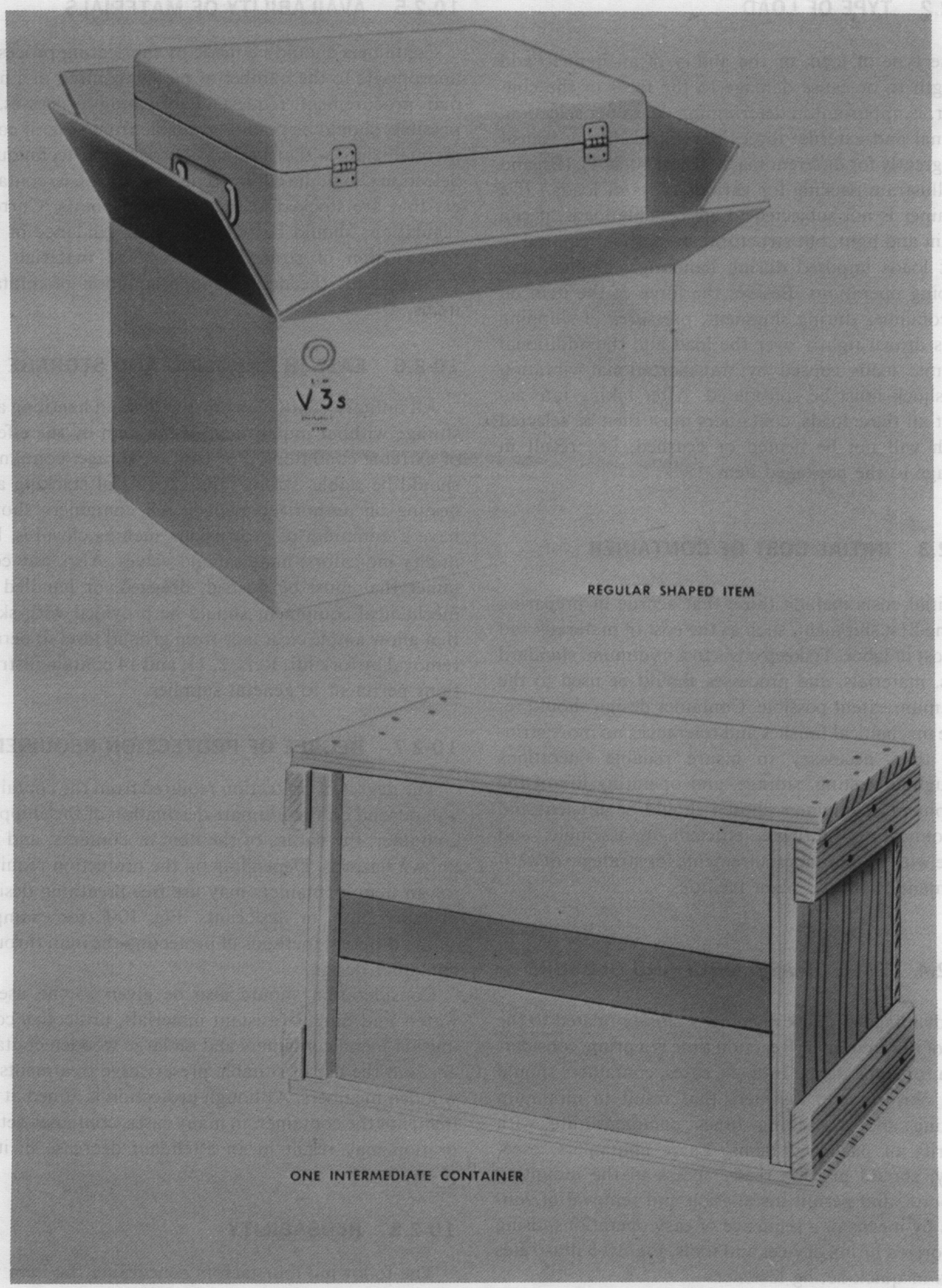

Fig. 10-2(A). Packing for Easy Loads

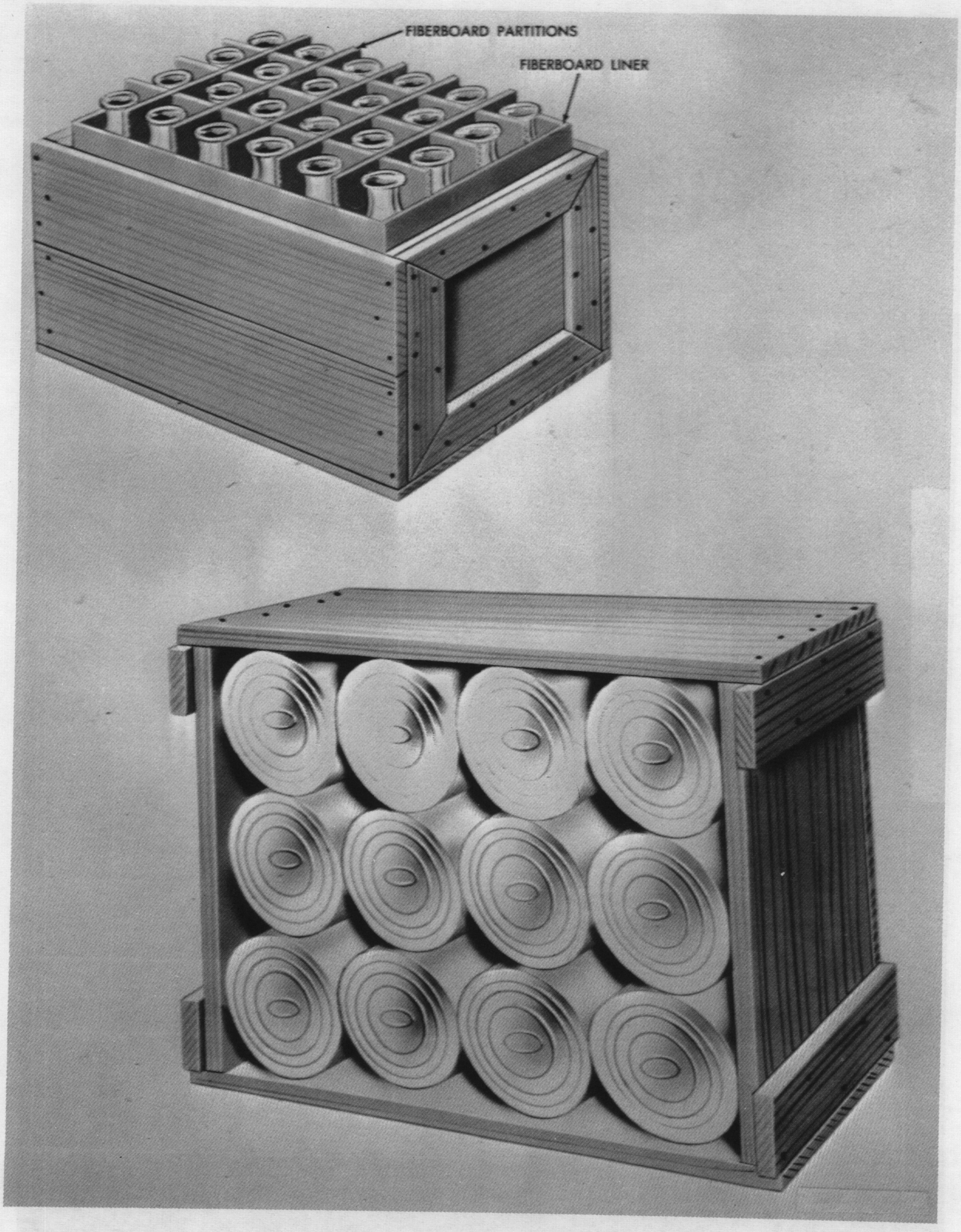

Fig. 10-2(B). Packing for Average Loads

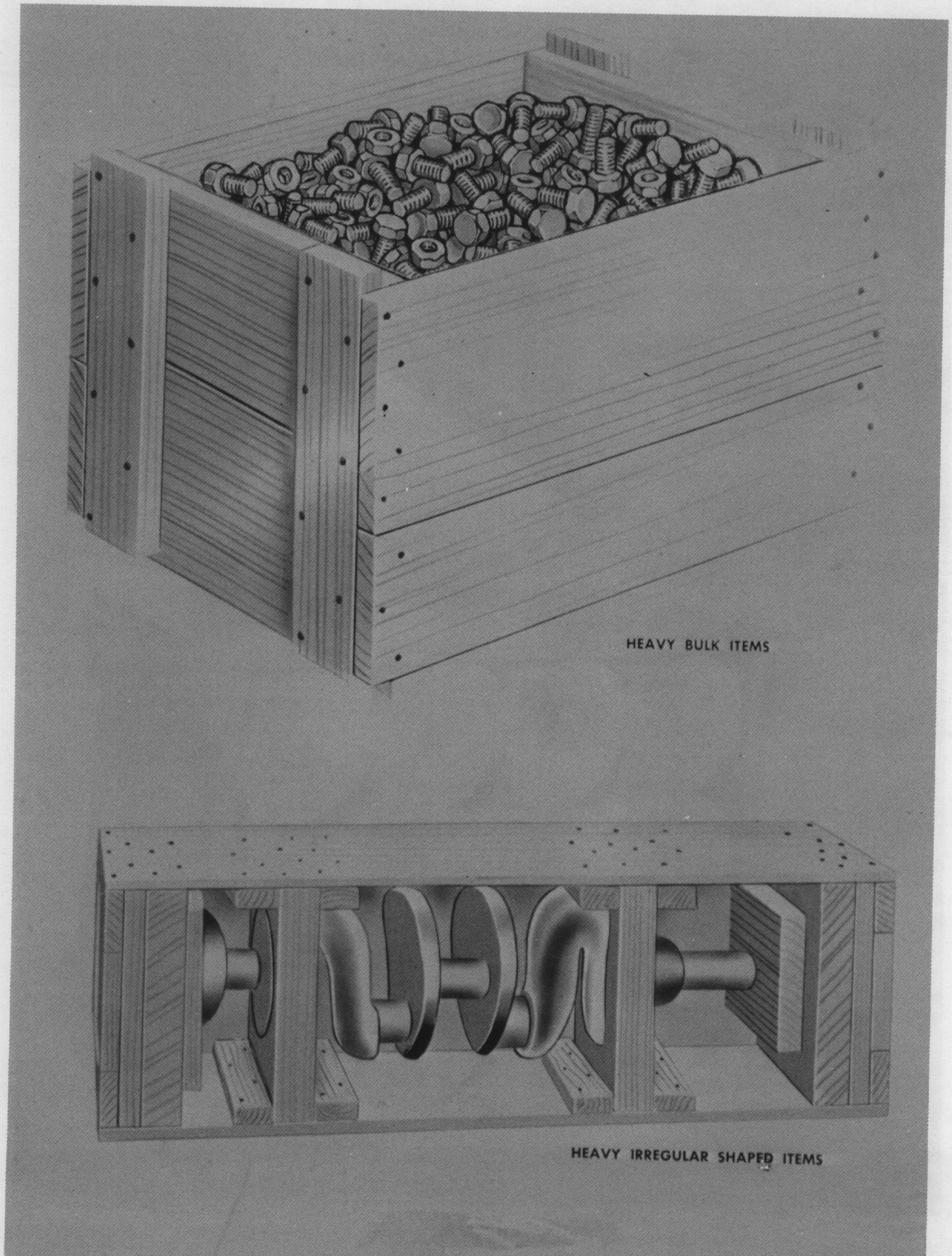

Fig. 10-2(C). Packing for Difficult Loads

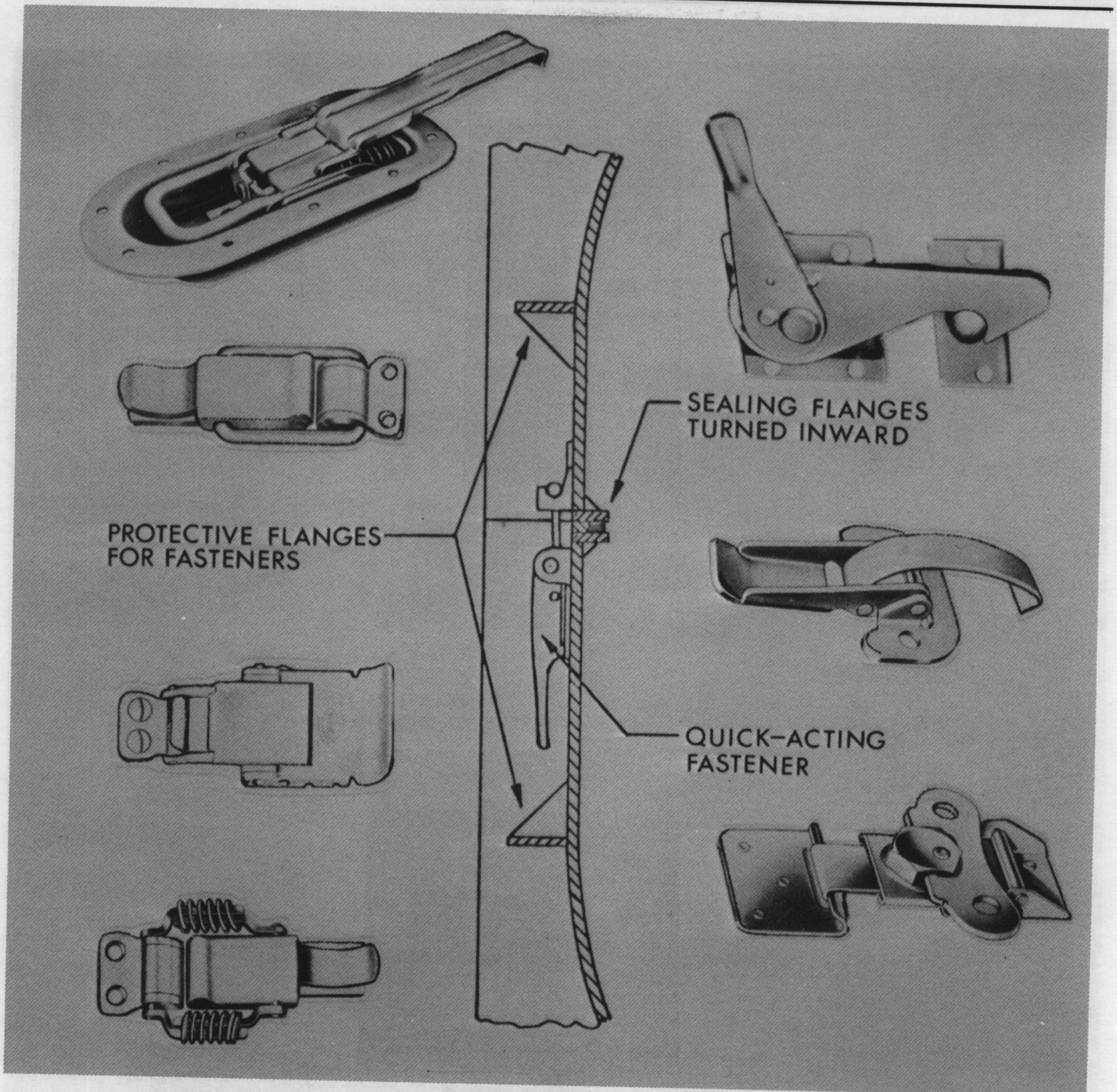

Fig. 10-3. Quick-acting Fasteners

(1) Military characteristics (this would be the overriding factor)

(2) Logistic characteristics

(3) Maintenance

(4) Repairability and recoverability.

Reusable containers are used to prevent unserviceability or damage to large, bulky, fragile, or expensive items that must be returned by the using or field maintenance organization or activity to a supply source or repair, or rebuilding facility. Reusable containers are especially useful for items of a critical nature which may have to be returned from the field where packing facilities are limited and inadequate to supply required protection.

Reusable containers are also useful for items to be shipped for testing or modification, and which will require subsequent repacking for shipment or storage. Such containers should be selected only if they are economically and logistically practicable. Features that contribute to excessive production costs, weight, and cube should be eliminated.

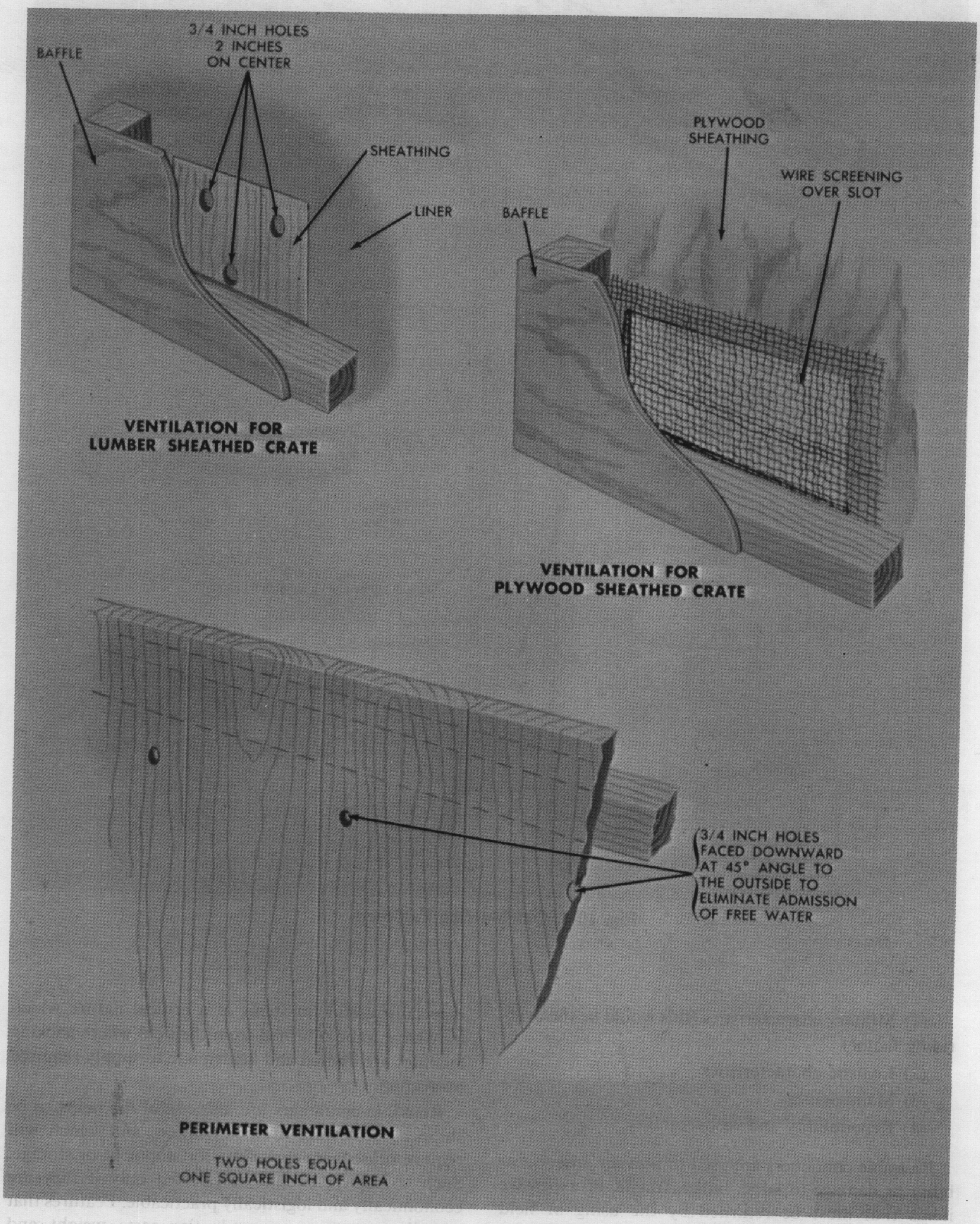

Fig. 10-4. Providing Ventilation for MIL-C-104 Crate[3]

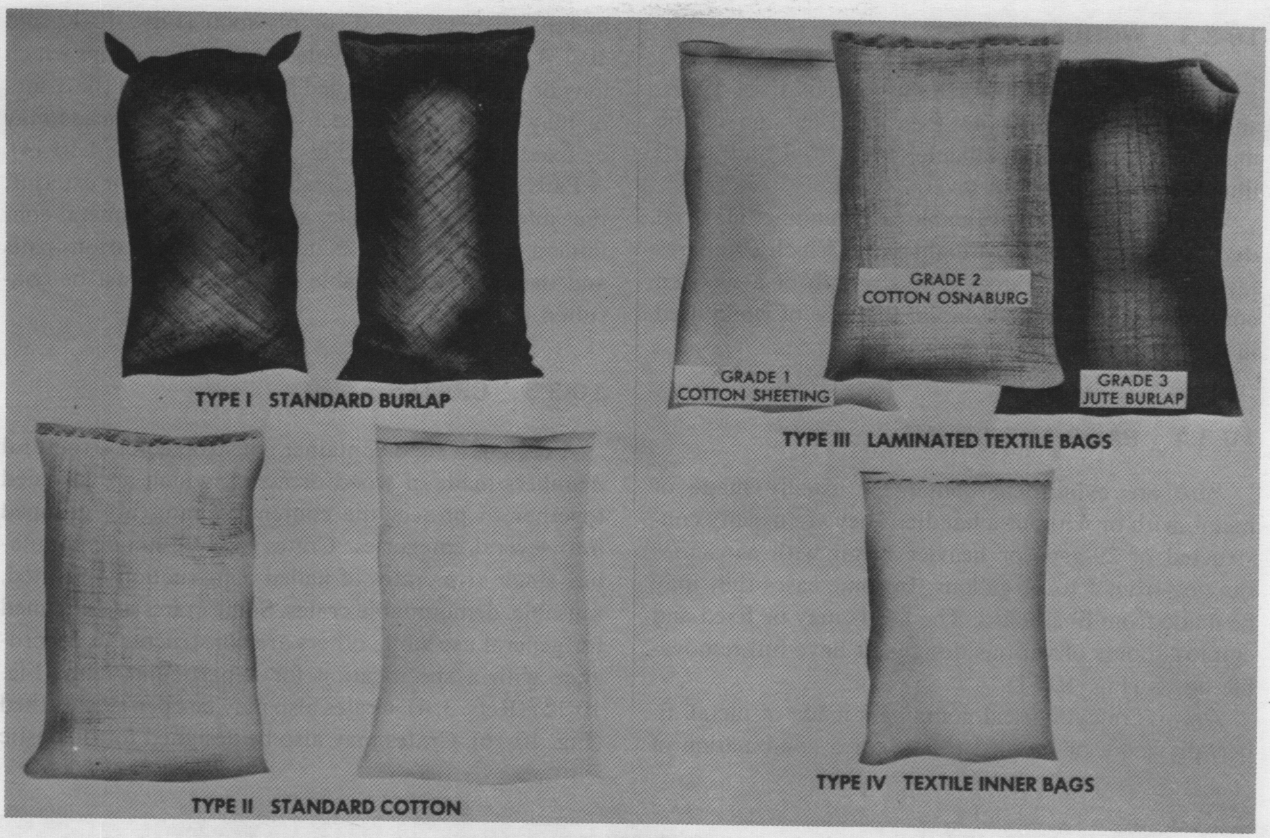

Fig. 10-5. Types of Textile Shipping Bags

10-3 STANDARD CONTAINERS

The most common types of containers in use today are bags and sacks, fiberboard and paperboard boxes, wooden boxes, pails and drums, and crates. Each has its uses and limitations and some are designed to handle specific items. These basic containers, as mentioned, are briefly described.

10-3.1 BAGS AND SACKS

A *bag* is a preformed container made of flexible material (Fig. 10-5) generally closed on all sides except one which forms an opening that may or may not be sealed after filling.

A *sack* generally refers to heavier duty or shipping bags (Fig. 10-6). Both bags and sacks may be employed to handle the same weights and kinds of commodities.

Bags and sacks possess the advantage of having low tare weight ratio, being flexible, providing ease in filling and handling, requiring a minimum of storage space, and being constructed of low cost materials (Ref. 1).

19-3.2 FIBERBOARD AND PAPERBOARD CONTAINERS

A fiberboard container is made of one or more pieces of corrugated or solid fiberboard. The pieces are creased, slotted, joined, and folded according to standard styles (Figs. 10-7 and 10-8).

A fiberboard box weighs considerably less than a wooden box of the same capacity. This difference in weight is a factor when large shipments are involved because any saving of weight is reflected in lower shipping costs and easier handling. The chief requirements for a shipping container are light weight, low cost, ability to protect the contents against loss or damage, and the ability to withstand rough handling. If a fiberboard box meets these requirements, it should be used. Types, classes and grades of fiberboard boxes can be found in Refs. 1, 7, and 10.

Paperboard containers are usually reserved for interior packaging. Depending on the item, a paperboard box may be used in packing when utilizing parcel post. Refs. 6, 8, and 9 give the requirements which must be met for paperboard containers.

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10-3.3 WOODEN BOXES

Wooden boxes are available in various sizes, types, and styles. Space does not permit discussion of the many wooden boxes available. Figs. 10-9 and 10-10 illustrate a few boxes of several styles.

Wood is particularly valuable as a container material due to its high strength-weight ratio, which compares favorably with mild steel. The strength of a wooden container depends largely upon the type of wood used in its construction (Ref. 5).

10-3.4 PAILS AND DRUMS

Pails are cylindrical containers usually made of metal, with or without a handle. They are usually constructed of 29-gage or heavier metal with capacities ranging from 1 to 12 gallons. In some cases they may be made from fiberboard. The heads may be fixed and employ spouts of various designs or have full removable heads (Fig. 10-11).

Drums are cylindrical containers made of metal, fiber, plywood, or molded plastic, or a combination of metal and fiber, wood, or plywood (Figs. 10-12 and 10-13). They may be provided with rolling hoops which may be pressed or expanded from the body of the drum, or may be I-bars welded to the body. The heads may be fixed or removable (Figs. 10-12, 10-13, and 10-14).

Pails and drums are classified as interior or exterior, reusable and nonreusable, and metal or nonmetal containers. For specific rules in the use of the various pails and drums, the applicable specification must be consulted (Ref. 1).

10-3.5 CRATES

A crate is a rigid container constructed of structural members made of wood or metal, which are fastened together to protect the contents. Crates are grouped into several categories. Crates may be nondemountable, single trip crates of nailed construction or bolted, reusable, demountable crates. Some crates are designed for general use while others are constructed in accordance with a specification for a particular item (Fig. 10-15) (Refs. 3, 4). Crates also may be open or sheathed (Fig. 10-16). Crates may also be designed for domestic

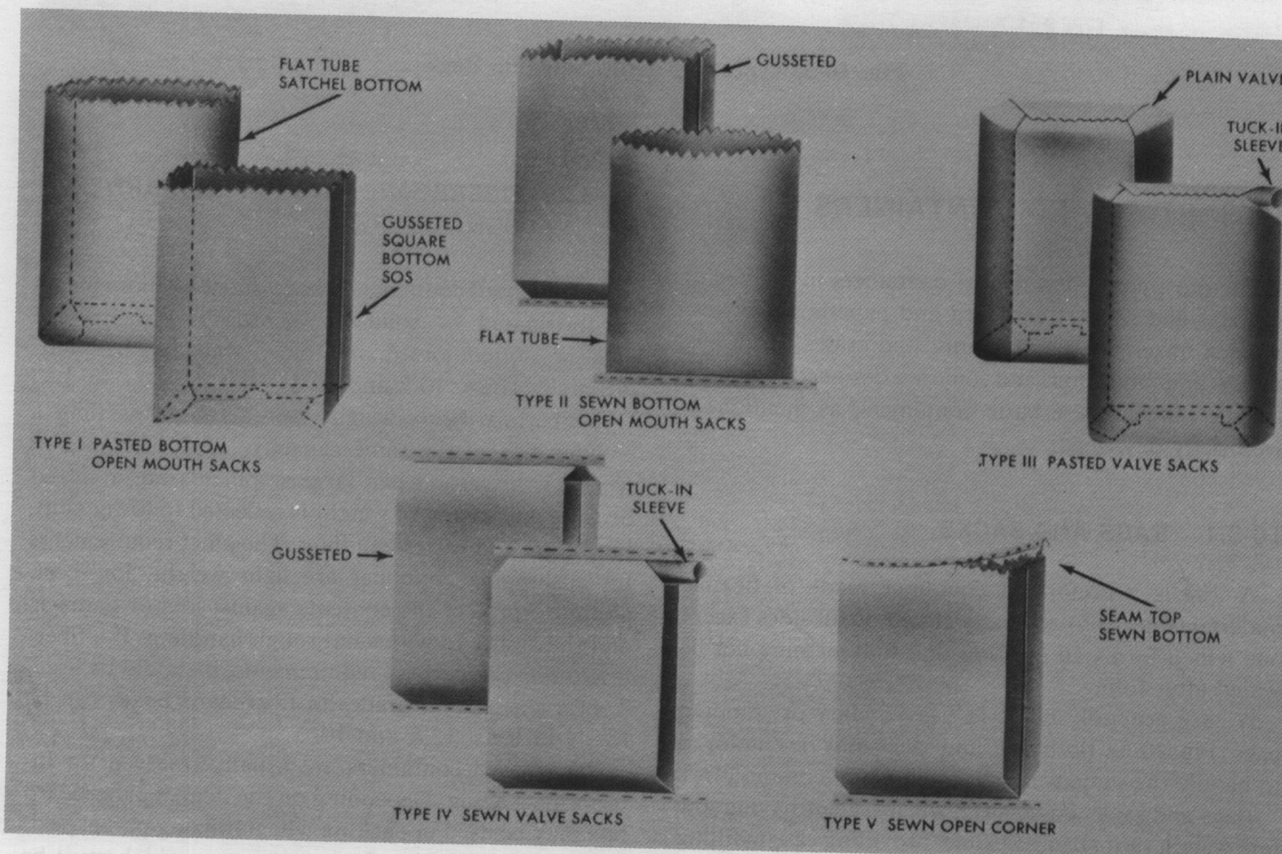


Fig. 10-6. Types of Paper Shipping Sacks

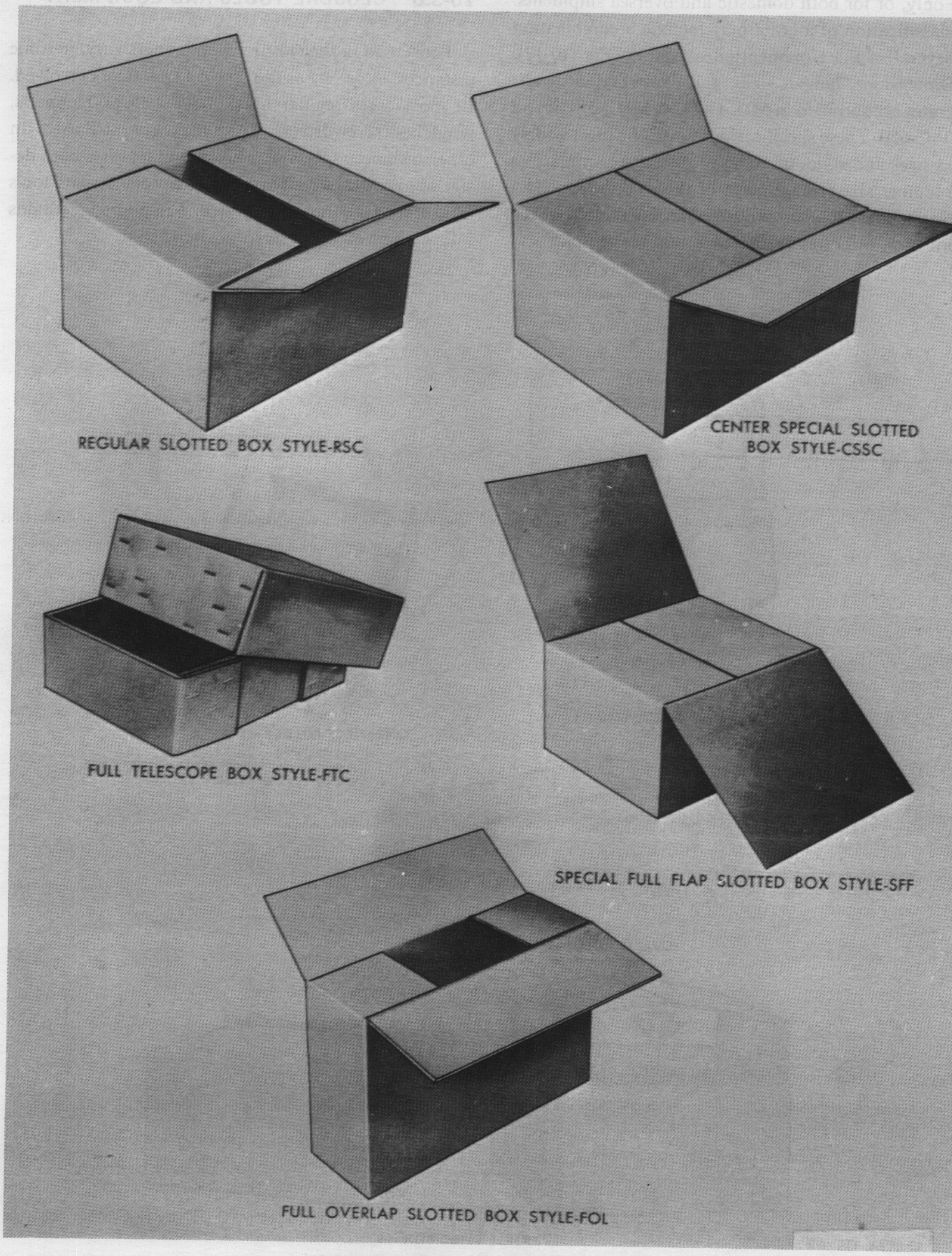


Fig. 10-7. Styles of Fiberboard Boxes

use only, or for both domestic and oversea shipments. A classification of a crate may include a combination of several of the aforementioned factors (Fig. 10-17).

Dimensions, lumber sizes, and construction details of crates are specified in MIL-C-3774, MIL-C-104, and PPP-C-650. These specifications cover the most widely used sizes and styles of crates. Table 10-1 summarizes the lumber size requirements of these specifications.

Nails, bolts, screws, and other fasteners used in the fabrication of crates are detailed in Chapter 11.

10-3.6 CLOSURE TOOLS AND EQUIPMENT

Tools used in the closure of containers vary, in some instances, as widely as the types of containers involved. In most cases regular hand tools such as hammers, wrenches, screwdrivers, drive bars, etc., are used. In other instances special closure equipment has been designed to ensure effective closures. Special closure tools in use are listed and illustrated. Chapter 11 contains information on closures in greater detail.

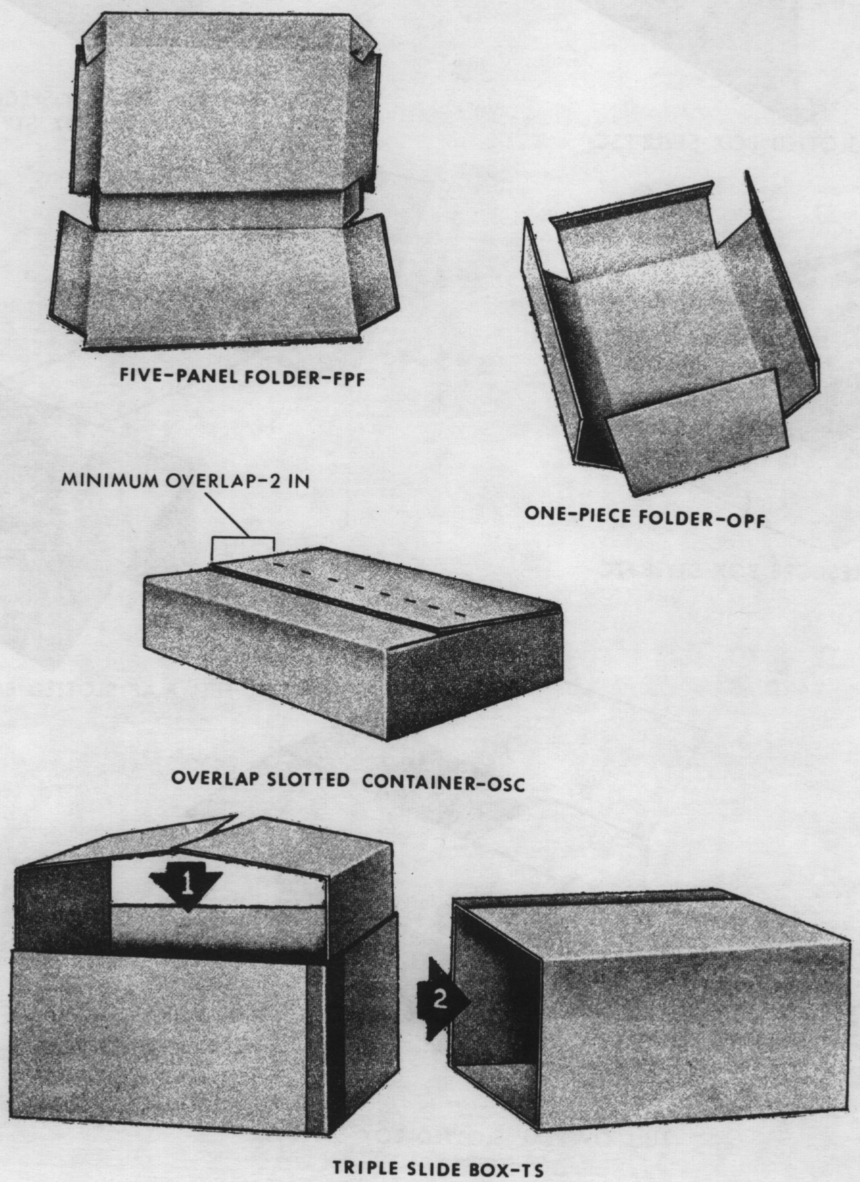


Fig. 10-8. Styles of Fiberboard Boxes

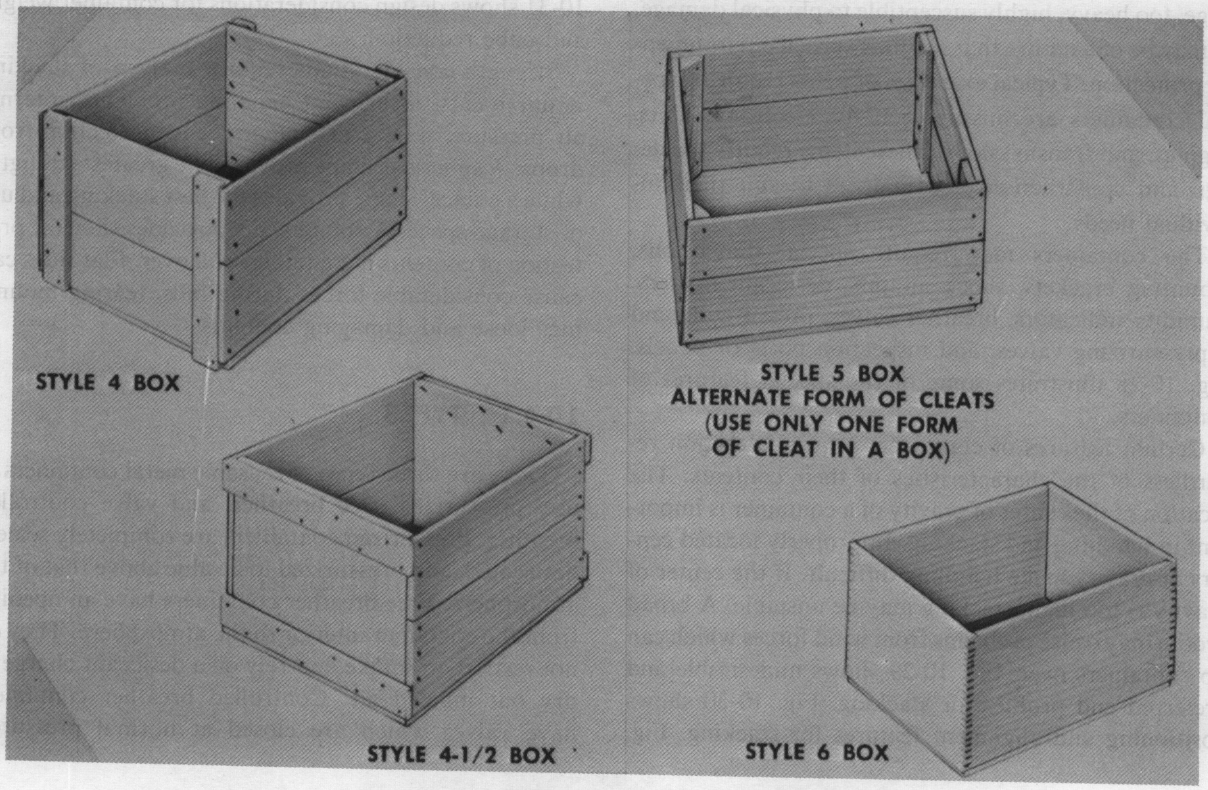


Fig. 10-9. Styles of Nailed Wooden Boxes

Steel shipping pails utilize a lug cover for closure purposes (Fig. 10-18). Lug covers may be secured by a tool specifically designed to accomplish closure on this type of container cover. Fig. 10-19 illustrates a machine which will close all lugs on a container cover in one operation; Fig. 10-20, a small hand tool which closes two lugs at a time. Hands, pliers, screwdrivers, hammers, or other improvised means are not satisfactory and should not be used.

Reusable steel shipping drums are divided into two groups. One type has a bolted ring-type cover with a gasket beneath the locking ring and is secured by means of a bolt and nut (Fig. 10-21). Only common hand tools are required to effect a satisfactory closure (Fig. 10-22). The second type uses the twist lock-type cover and closure is accomplished by screwing the threaded cover into engaging threads on the body of the container (Fig. 10-21). Special tools have been designed for closure of this twist lock-type cover (Fig. 10-23). A driving bar (Fig. 10-24) or pneumatic hammer (Fig. 10-25) may also be used to ensure an effectively tight closure.

Wirebound wooden boxes require special tools designed specifically for this type of closure. For closure of Style 1 wirebound wooden boxes there are three choices of special tools available: a hand twister, a crank twister, or a power twister (Fig. 10-26). The closure of Style 2 and Style 3 wirebound wooden boxes requires the use of a Sallee closer (Fig. 10-27). The use of common hand tools, such as screwdrivers, pliers, etc., to effect a closure of wirebound wooden boxes, is not recommended because an adequate closure cannot be made and their use may be a safety hazard (Ref. 17).

10-3.7 REFERENCE

Par. 10-3 is an extremely brief sampling of the many types of containers available for use. Space does not permit full coverage of these items. There are, for example, many more styles, classifications, and types of crates which have not been shown or discussed. For more detailed information on crates and other containers mentioned in this paragraph, consult the applicable specification or standard.

10-4 REUSABLE METAL CONTAINERS

Some military supply items cannot be packed using available exterior containers. The items may be too

large, too heavy, highly susceptible to physical damage, or may be of a nature that requires special environmental protection. Typical examples of items requiring special containers are missile sections, electronic units, engines, and transmissions. These items require the design and construction of containers to suit their individual needs.

The containers may require special dimensions, mounting brackets, shock mounts, desiccant holders, humidity indicators, breather valves, pressurizing and depressurizing valves, and inspection ports or panels. Fig. 10-28 illustrates some of the special features of containers.

Certain features of containers require attention regardless of the characteristics of their contents. The location of the center of gravity of a container is important in handling and stacking. Improperly located centers of gravity make handling difficult. If the center of gravity is too high, stacking may be unstable. A broad profile may cause problems from wind forces which can tip containers over. Fig. 10-29 shows undesirable and preferred end profiles for stacking. Fig. 10-30 shows positioning and alignment features for stacking. Fig. 10-31 shows design considerations for container weight and cube reduction.

Strength considerations require analysis of stacking requirements, lifting and handling problems, internal air pressure, weight of contents, and protection from drops. A spherical shape provides the greatest strength, while a cubical shape provides the best stacking and use of storage space. A round shape provides the best protection of contents if containers roll over. Flat sides can cause considerable forces during falls, tearing mountings loose and damaging contents.

10-4.1 TYPES

There are three types of reusable metal containers in use: pressurized, free breather, and valve controlled breather. Pressurized containers are completely sealed, desiccated, and pressurized to a value above that of the atmosphere. Free breather containers have an opening from the container interior to the atmosphere. They do not restrict air intake, but rely on a desiccant charge to dry out inhaled air. Controlled breather containers have valves which are closed at normal pressures.

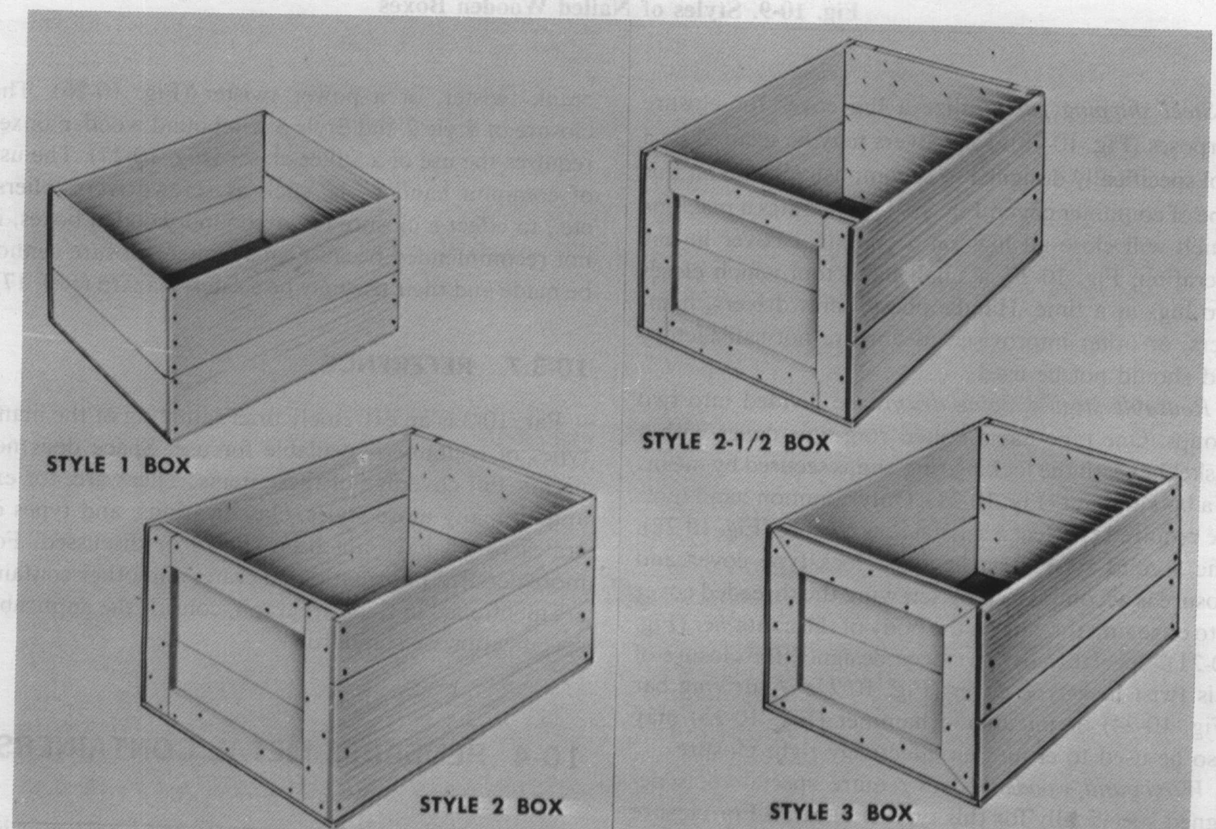


Fig. 10-10. Styles of Nailed Wooden Boxes

When the container interior pressure is too high or too low the valves open to relieve the pressure. In this way the amount of breathing is reduced and desiccant life increased.

Pressurized containers offer the greatest protection but are heavy and bulky since they must be made strong enough to withstand the pressure changes caused by temperature variations and altitude changes in airlift operations. The life of desiccant in pressurized containers is indefinite as long as the containers remain pressurized.

Free breather containers can be made lighter and smaller than pressurized containers. The strength required is limited to that necessary to withstand handling and stacking forces. The continual breathing, however, allows a considerable amount of atmospheric moisture to enter the container and this soon saturates the desiccant. The life span of the desiccant in a free breather container is approximately 6 months to one year depending on atmospheric humidity conditions and breather hole size.

Controlled breather containers are a compromise between pressurized and free breather containers. By selecting breather valves with a proper operating pressure, breathing can be reduced, and the life of the desiccant extended for a considerable period of time. The valves also allow the container to be less heavily constructed than a pressurized container since only moderate pressures can build up inside. No definite life span can be given for controlled breather containers because the life varies with the valve settings and the atmospheric conditions, but the life can be several years.

Fig. 10-11. Tight Head and Lug Covered Pails

10-4.2 TEMPERATURE AND PRESSURE CONSIDERATIONS

Atmospheric temperature variations affect a metal container in several ways: (1) they change the container internal temperature; (2) they change the container internal pressure; and (3) they change container internal relative humidity.

The container internal temperatures are affected by the direct contact with the atmosphere resulting in heat conduction and also by solar radiation directly on the surface of the container. At night containers assume the temperature of the ambient atmosphere. During a bright day, the internal temperature reaches a value determined by solar radiation. On cloudy days the temperature tends to closely approximate ambient temperature. The only effective method of protecting container contents from these temperature variations is to store the containers in a shaded location.

Temperature changes cause container internal pressures to change due to expansion and contraction of the contained air. The effect can be quite severe over a one year period since container interior temperatures can be as low as $-15°$ or $-20°$F and as high as 165°F due to solar radiation. Pressure variations due to change in atmospheric pressure are not severe at any one given altitude and can be considered negligible. The variations in pressure due to altitude changes, as found in airlift operations, are quite severe. Pressure changes from altitude are shown in Fig. 10-32. These are the pressure changes that must be compensated for in container strength or by breather valves.

The effect of temperature on container relative humidity is shown in the psychrometric chart of Fig. 14-4. Briefly, the effect is the relative humidity decreases as temperature rises and increases as temperature drops. The only practical method of compensation for this is proper humidity control through the use of desiccants.

10-4.3 BREATHER VALVES

A breather valve must perform two functions: (1) prevent the entry of moisture into the container; and (2) prevent the build-up of excessively high pressures or vacuums which may damage the container. To accomplish this the valve must have a low leakage rate, a high cracking (operating) reliability, and a high flow rate after cracking.

Excessive valve leakage permits a container to breath before the designed cracking pressure is reached and can reduce container life. Leakage to some extent is unavoidable since no valve seal is perfect. However, leakage must be kept to the lowest value possible. When a valve nears its cracking pressure, it begins to unseat and will leak before it actually cracks. The same situation occurs when a valve reseats; some leakage will occur before total reseating. Careful consideration should be given to this factor when selecting a valve. Leakage is also a function of valve age and environment which can deteriorate the valve seat and spring. Therefore careful consideration should be given to materials used in construction. Foreign particles entering the valve can cause malfunction if a screen or protective cover is not provided.

Breather valves are available in almost any cracking pressure range desired. Pressures for containers may vary anywhere from 1/2 to 10 psi. The correct pressure to select is dependent on a number of variables. The higher the cracking pressure the less often a valve will breathe, but the heavier and stronger the container must be made to withstand the pressure. A choice must be made according to container design strength, desiccant load, and desired life of the container. High accuracy in cracking pressure is not necessary; positive cracking action is critical, however, since failure to crack can damage the container.

MIL-V-27166 specifies three types of breather valves: (1) vacuum relief, (2) pressure relief, and (3) combined vacuum and pressure relief. The selection of the type depends on the container design configuration (Ref. 12).

Flow rates of container valves are dependent on the maximum pressure differential expected to be built up in the container, and in the case of airlift the rate of pressure change caused by aircraft ascent and descent. The minimum acceptable flow rate (ft^3/min) from MIL-V-27166 is calculated as follows:

Fig. 10-12. Types of Fiber Drums and Closures

$$0.12\,(V_c - V_m),\ \text{ft}^3/\text{min} \qquad (10\text{-}1)$$

where

V_c = volume of container, ft^3
V_m = minimum volume of material in container, ft^3

Since the volume of the container contents may vary, or the container may be airshipped empty, it may be desirable to calculate flow rate with an empty container for a safety factor.

Valves should be located on a container in a place where water drops, dew, snow, or ice cannot collect on the valve inlet causing possible closure of inlet. If water collects on the inlet during a breathing-in period, a considerable amount of water can be inhaled.

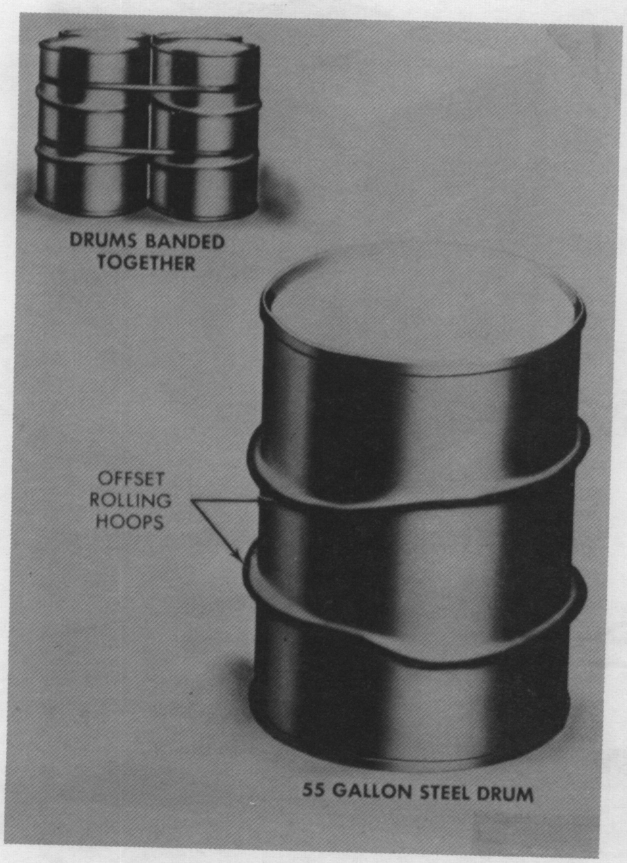


Fig. 10-13. Drum With Offset Rolling Hoops

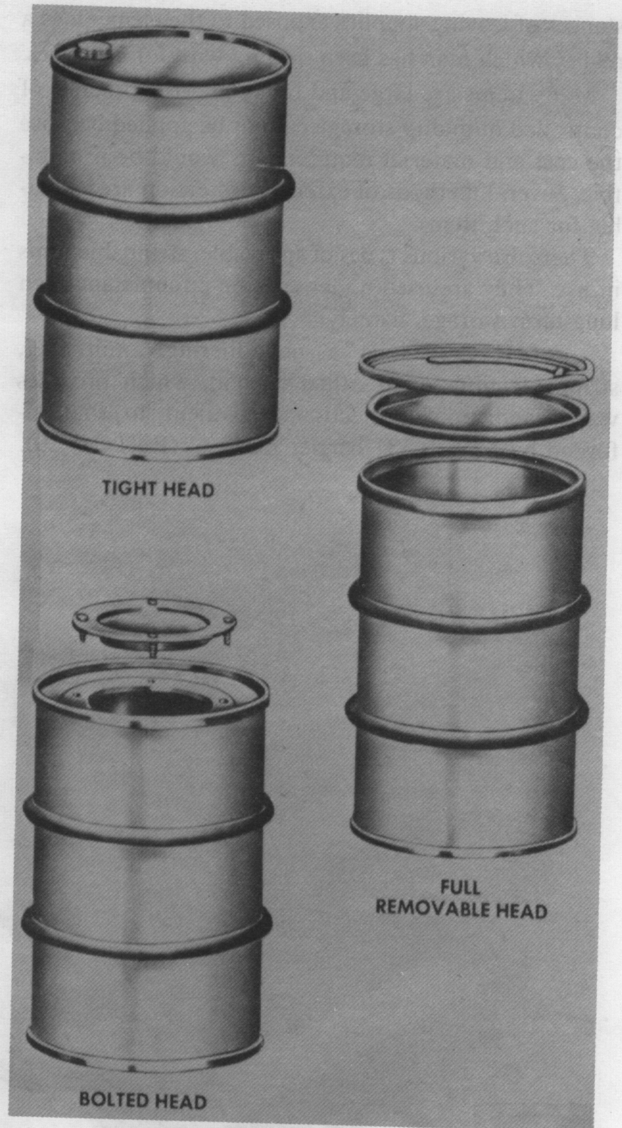


Fig. 10-14. Types of Drum Closures

10-5 OTHER EXTERIOR PROTECTION DEVICES

The ideal material storage situation would be, theoretically, a controlled humidity building where one can be reasonable certain that the stored material will be subjected only to a climate conducive to long-term storage. In military operations, this panacea does not exist, and proper and more costly preservation and packaging methods must be adopted as is discussed in previous chapters of this handbook. In the event of quick deployment of men and materiel, the circum-

stances of leaving supplies exposed to the elements is a reality which man has been dealing with for centuries.

Many items are large and bulky and the practice of controlled humidity storage cannot be applied because the cost and material requirements would be prohibitive. Several methods of exterior protection are available for such items.

There are various types of sprayable, strippable films in use. They are used under specific circumstances on long-term storage, namely:

a. MIL-C-3254 is a nonadhering, multilayer, strippable film, often called cocoon, which provides water-vaporproof protection equivalent to that afforded by MIL-B-131 barrier material (Refs. 18, 19).

b. MIL-C-16555 is a strippable coating intended to protect metal and fabric surfaces from deterioration and physical damage on items in outdoor storage and during shipment (Ref. 20).

c. MIL-C-6799 covers other types of strippable coatings which are used according to type and class. The standard should be consulted for guidance since it includes items such as entire aircraft, missiles, and vehicles (Ref. 21).

Figs. 10-33 and 10-34 depict the coats of strippable compounds required for protection of large items. More complete information on the type and class of

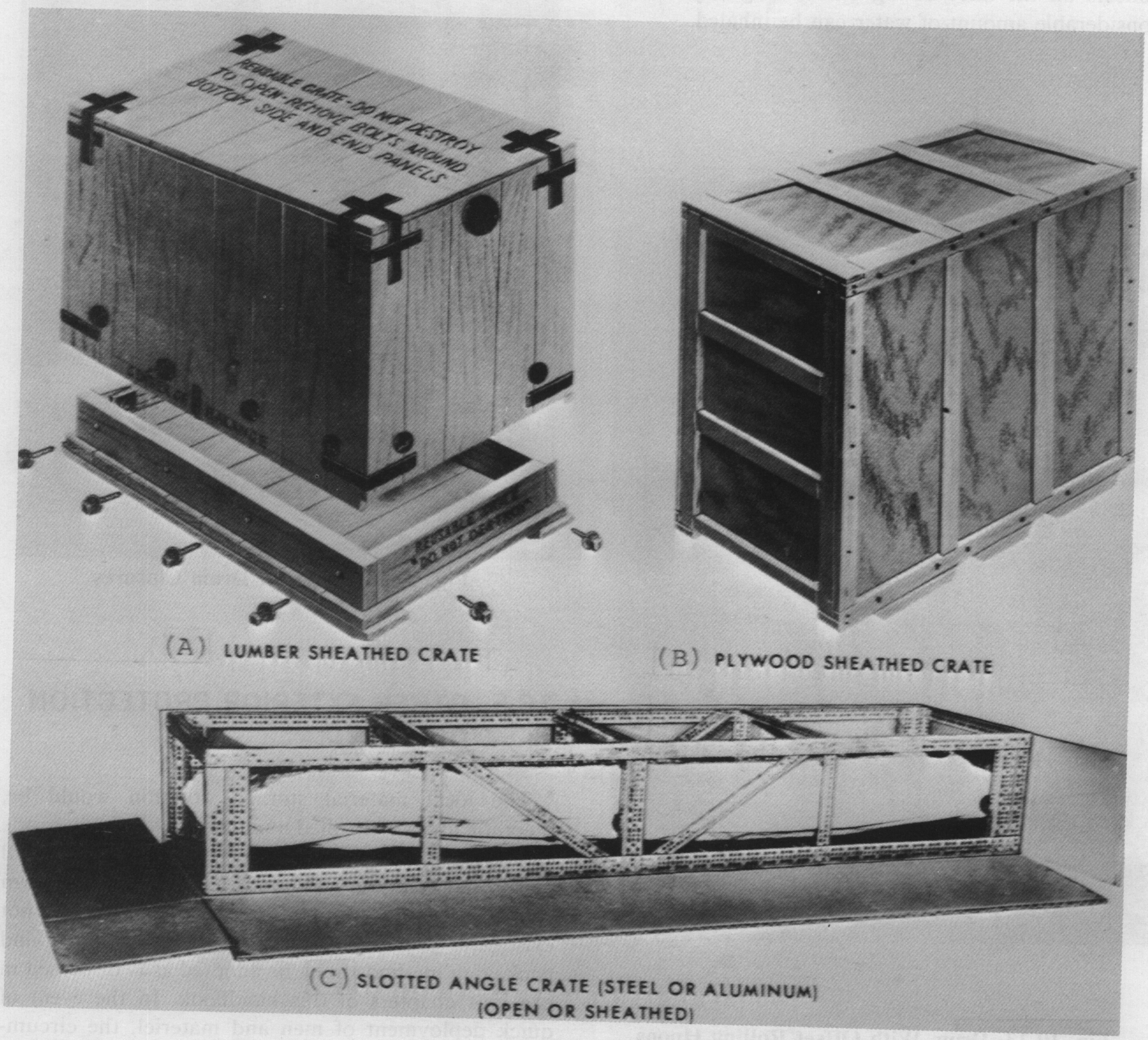


Fig. 10-15. Special Use Crates

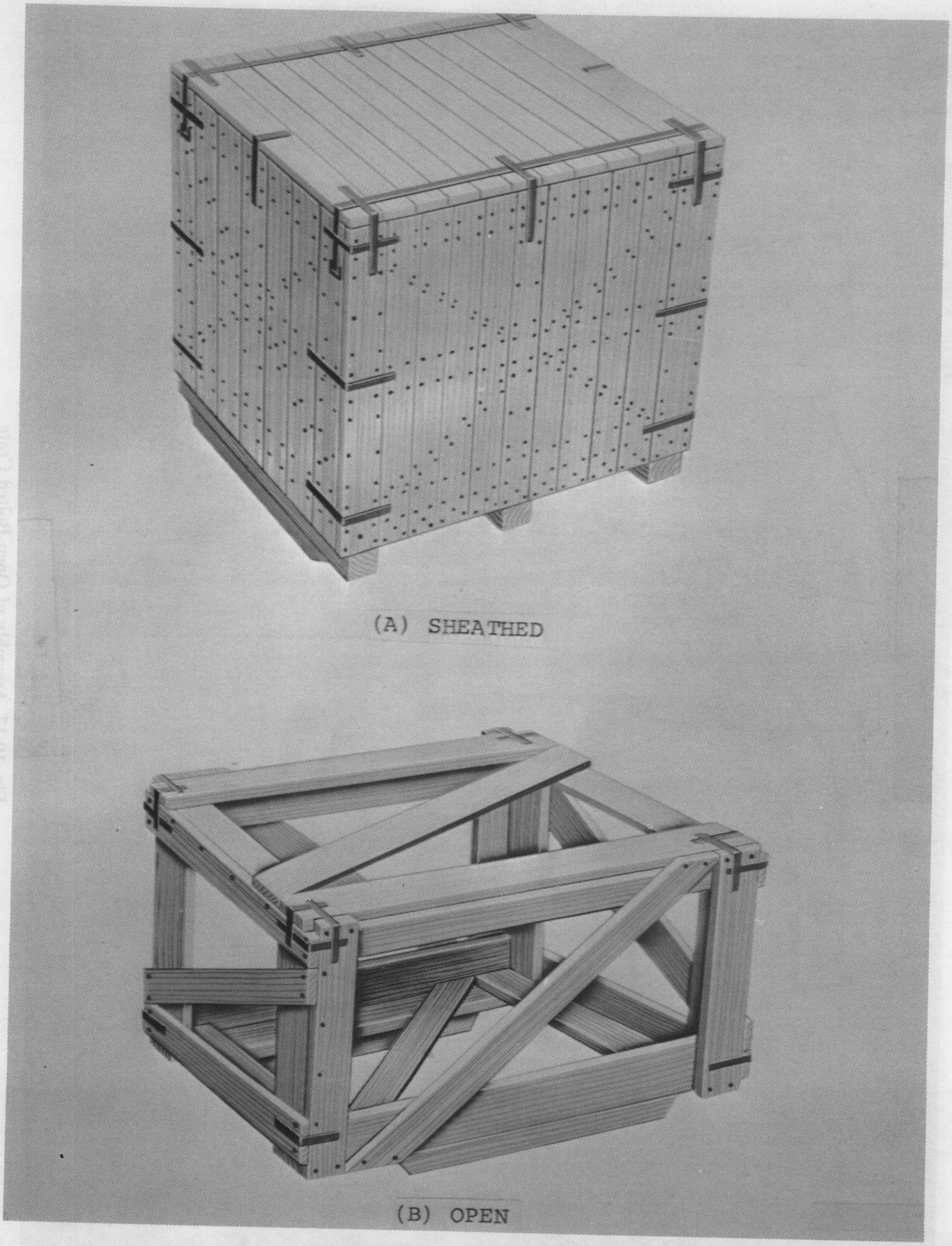


Fig. 10-16. Open and Sheathed Crates

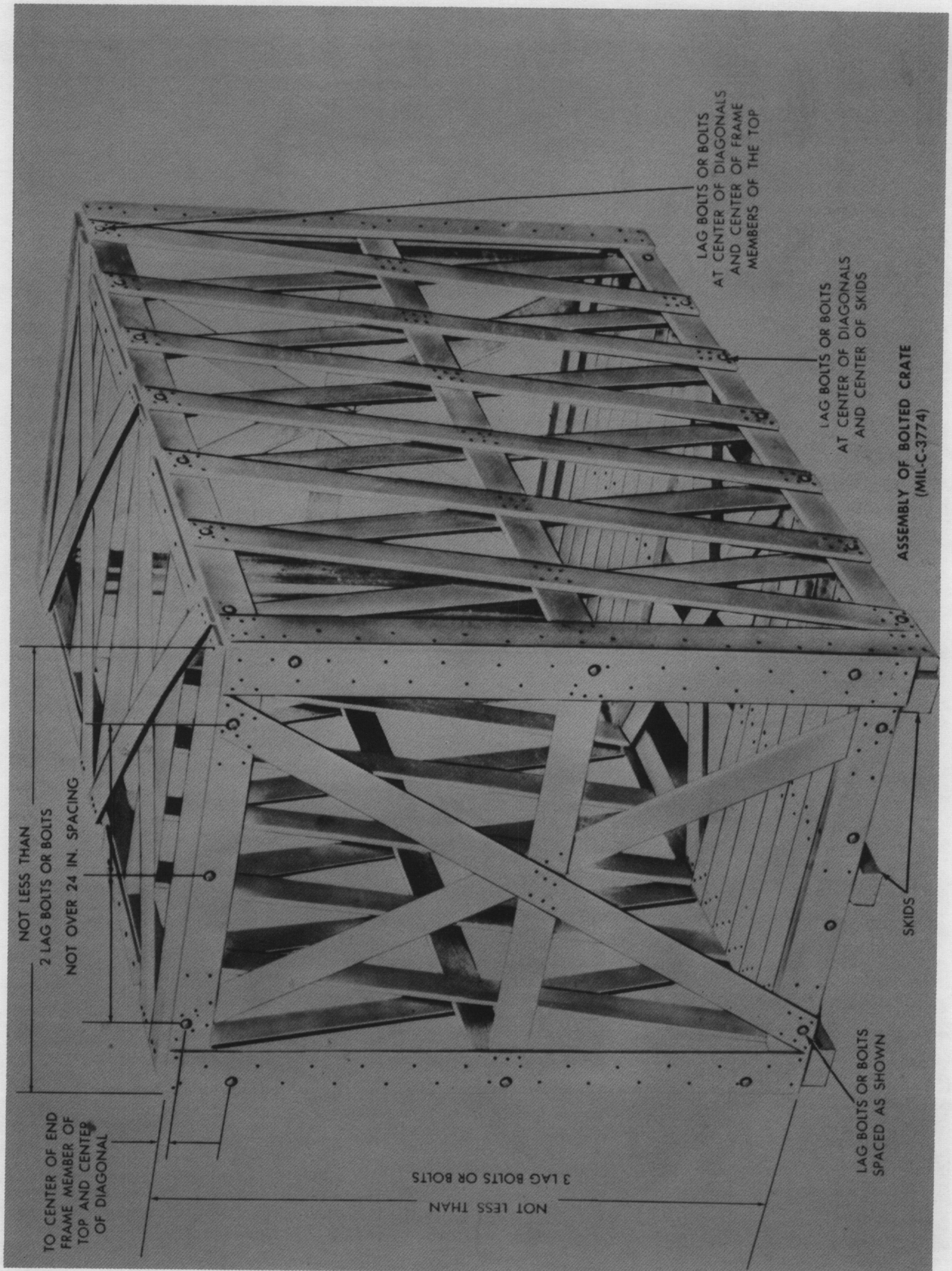


Fig. 10-17. Assembly of Open Bolted Crate

film required for application can be found in TM 38-230-2 (Ref. 1).

10-5.1 PALLETS

A pallet is a portable platform upon which material is placed to facilitate handling and transportation. This platform is generally a two-deck structure which permits mechanical handling and tiering of unit loads of supplies and equipment.

Pallet types are classified as expendable or permanent, and also as general purpose or special purpose, namely:

a. *Expendable pallets* are usually made of wood, fiberboard or both, and are used for one shipment and then discarded (Fig. 10-35).

b. *Permanent pallets* are labeled as general purpose or special purpose.

c. *General purpose pallets* are of a standard size and made of hard wood. Two general purpose pallets are the four-way entry post pallet and the four-way (partial) four stringer pallet (Fig. 10-36).

d. *Special purpose pallets,* which are made of metal, are suitable for certain heavy duty usage. They are more rugged and can withstand the abuse better than wooden pallets.

MIL-STD-147 gives the palletized unit load requirements for Department of Defense materiel using the two pallets mentioned. The Standard establishes loading patterns for various types of commodities, listing the pattern for stacking containers and methods of unitizing to be used and the limitations imposed (Ref. 11).

10-5.2 CONSOLIDATION FOR SHIPMENT

Consolidation is the combining of like or unlike items into a containerized or palletized load. This method results in economy through reduced handling and documentation, one unit taking place of several units (Refs. 15, 16).

One example of consolidation containers is the reusable metal shipping box (CONEX). The box is made of steel; is transportable; and has a maximum load capacity of 9,000 lb. There are two types of this container (Fig. 10-37), namely:

(1) *Type 1* with a capacity of 135 ft^3 and weight limitation of 9,000 lb.

(2) *Type 2* with a capacity of 295 ft^3 and a weight limitation of 9,000 lb.

Another example is palletization–i.e., placing of a number of packages on a low, portable platform of wood, metal, or fiberboard, or a combination of these materials (Fig. 10-38).

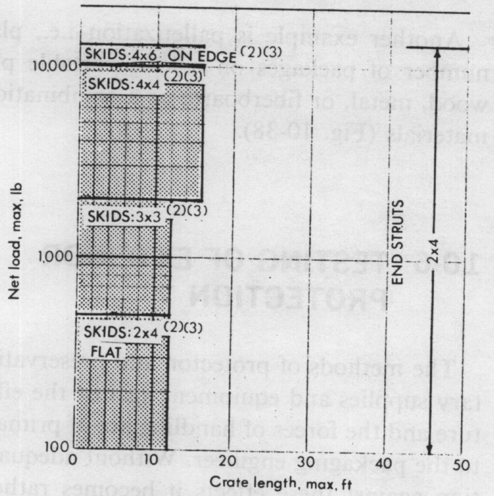
10-6 TESTING OF EXTERIOR PROTECTION

The methods of protecton and preservation of military supplies and equipment against the effects of nature and the forces of handling are of primary concern to the packaging engineer. Without adequate preparation against these effects it becomes rather doubtful whether any item of equipment will be capable of serving its purpose once it comes into the possession of the user. Accordingly, adequate and frequent test procedures must be established to properly test and evaluate all methods of preservation, packaging, and packing.

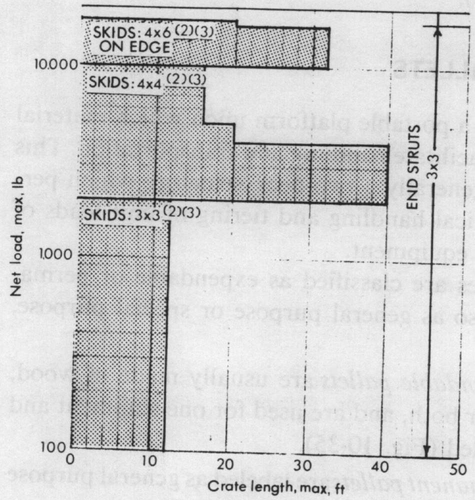
Exterior containers of new design and materials must be tested and evaluated for their ability to extend protection to the contents which they were designed to hold. Chapter 17, Testing and Inspection, outlines test requirements and procedures for evaluation of preservation, packaging and packing.

Fig. 10-18. Lug Cover Pail

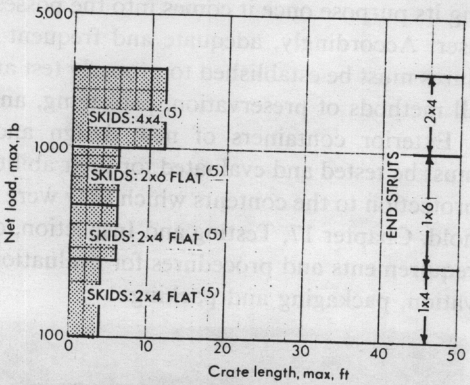
TABLE 10-1
LUMBER SELECTION CHART FOR CRATE SKIDS AND END STRUTS



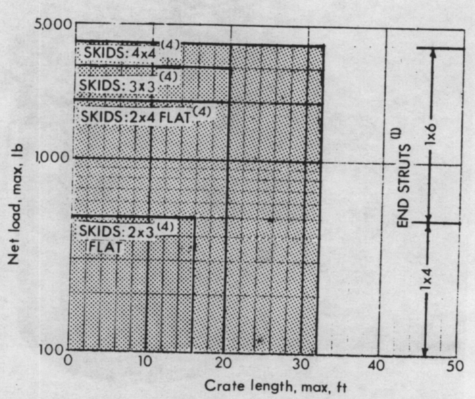
(A) MIL-C-3774, TYPE I



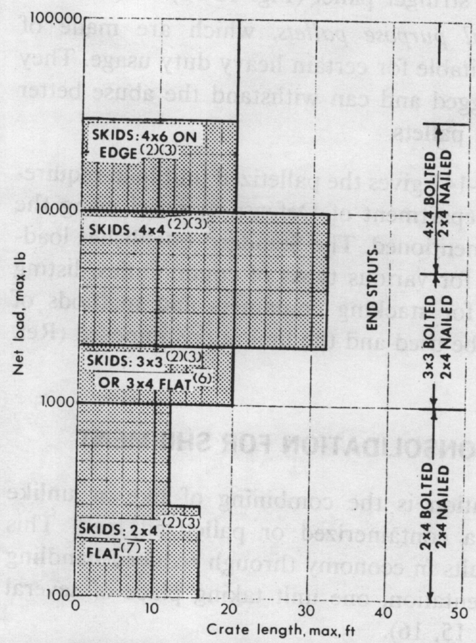
(B) MIL-C-3774, TYPE II



(C) PPP-C-650, STYLE A



(D) PPP-C-650, STYLE B



(E) MIL-C-104, TYPES I & II

Notes:

(1) For crates over five feet high, use 2x4 end struts.

(2) When maximum crate length or weight are exceeded, use next larger size lumber for skids. For example, in chart A, a 200 lb crate, 15 ft long would require 3x3 skids.

(3) Maximum distance between skids shall be 48 inches center to center. With concentrated loads, intermediate skids may be used.

(4) For crates up to 42 inches wide, use two skids. Over 42 inches, use three skids.

(5) For loads up to 1,000 lb, use two skids. Over 1,000 lb, use two skids for crates under three feet wide, and three skids for crates over three feet wide.

(6) For crates with 2 inch end struts or lower frame members.

(7) For nailed crates only.

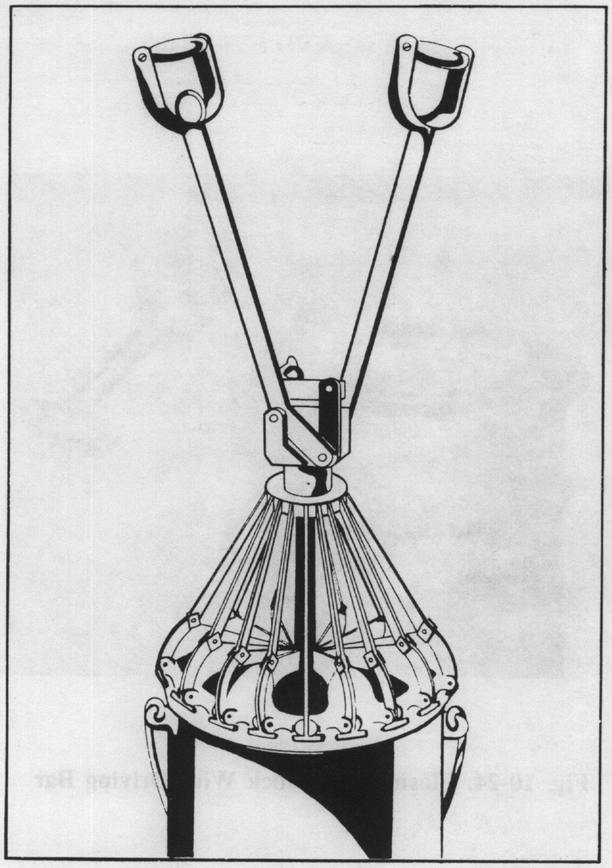


Fig. 10-19. Lug Cover Closing Machine

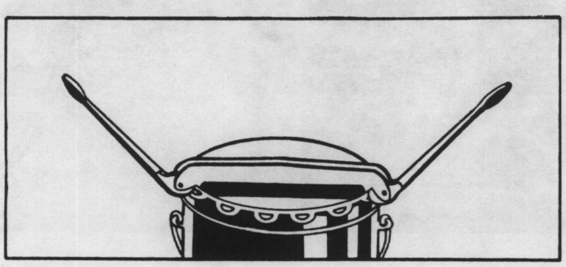


Fig. 10-20. Hand Closing Tool for Lug Covers

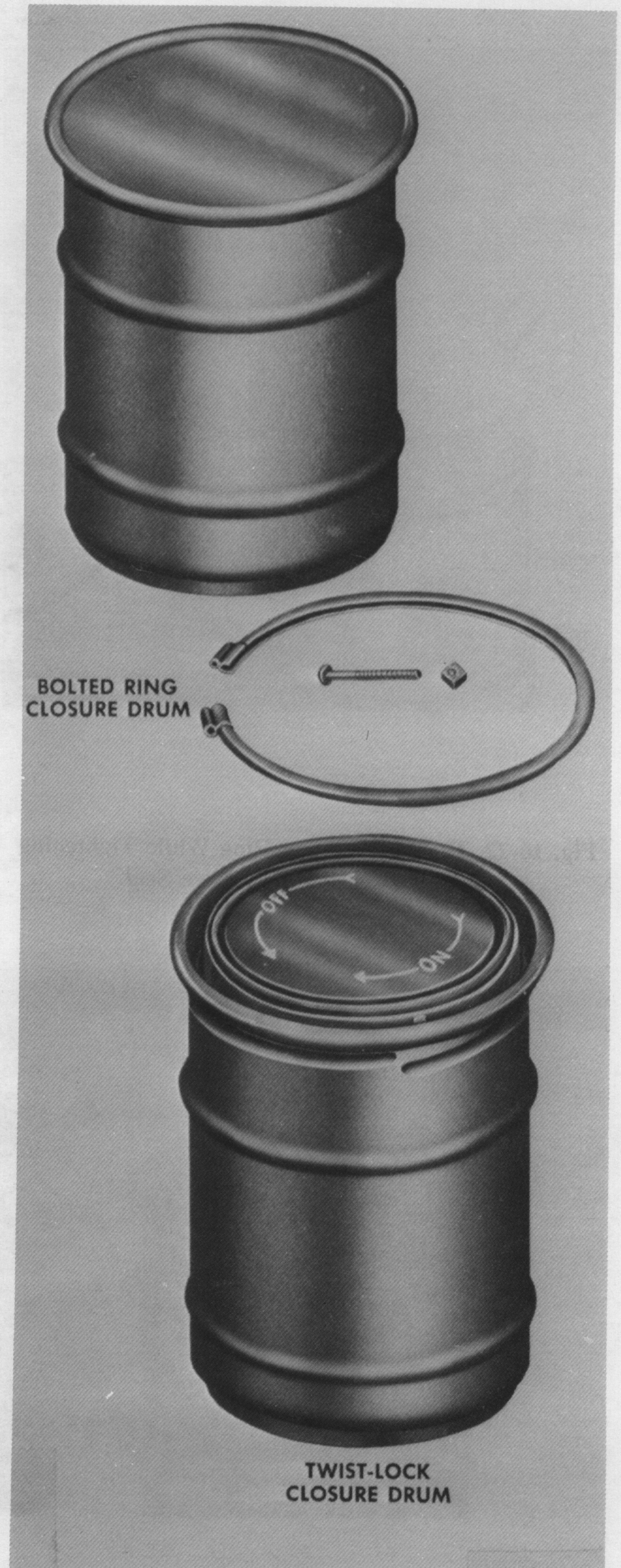


Fig. 10-21. Bolted Ring and Twist-lock Closures

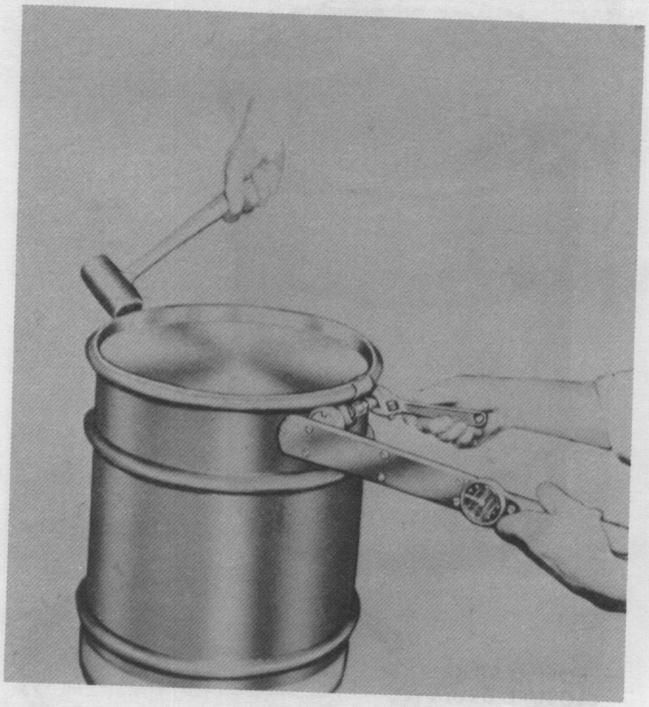


Fig. 10-22. Tapping Locking Ring While Tightening Bolt to Ensure an Effective Seal

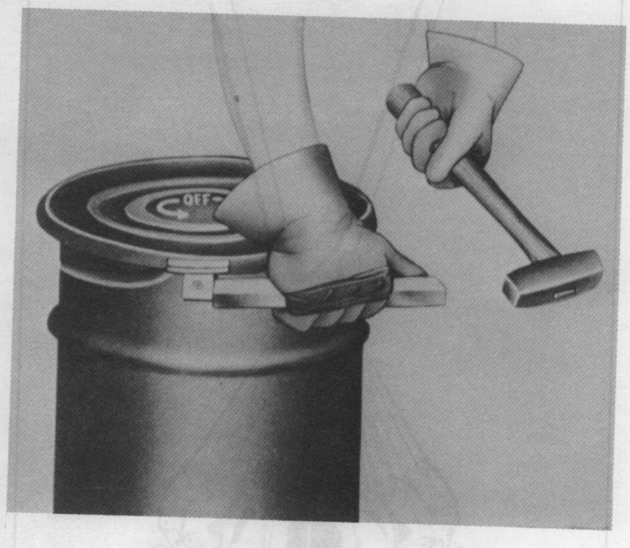


Fig. 10-24. Closing Twist-lock With Driving Bar

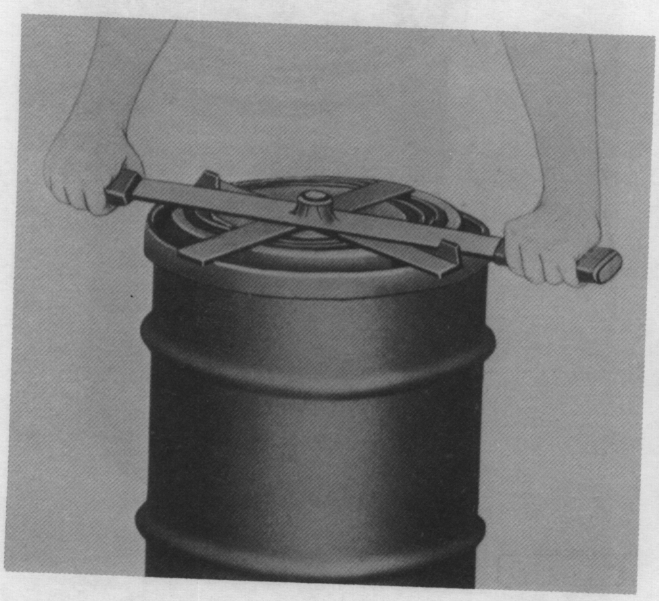


Fig. 10-23. Closing Twist-lock With Special Tool

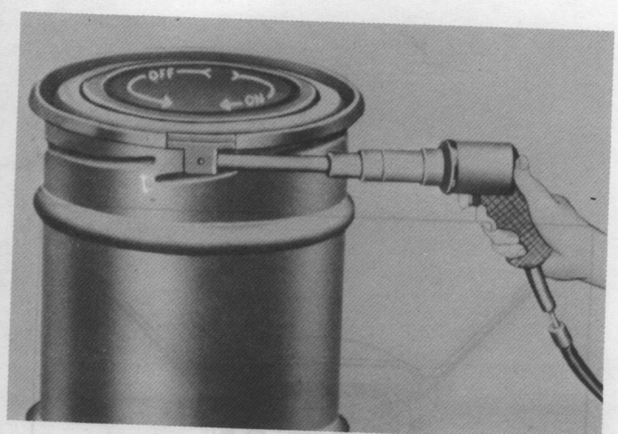


Fig. 10-25. Closing Twist-lock With Pneumatic Hammer

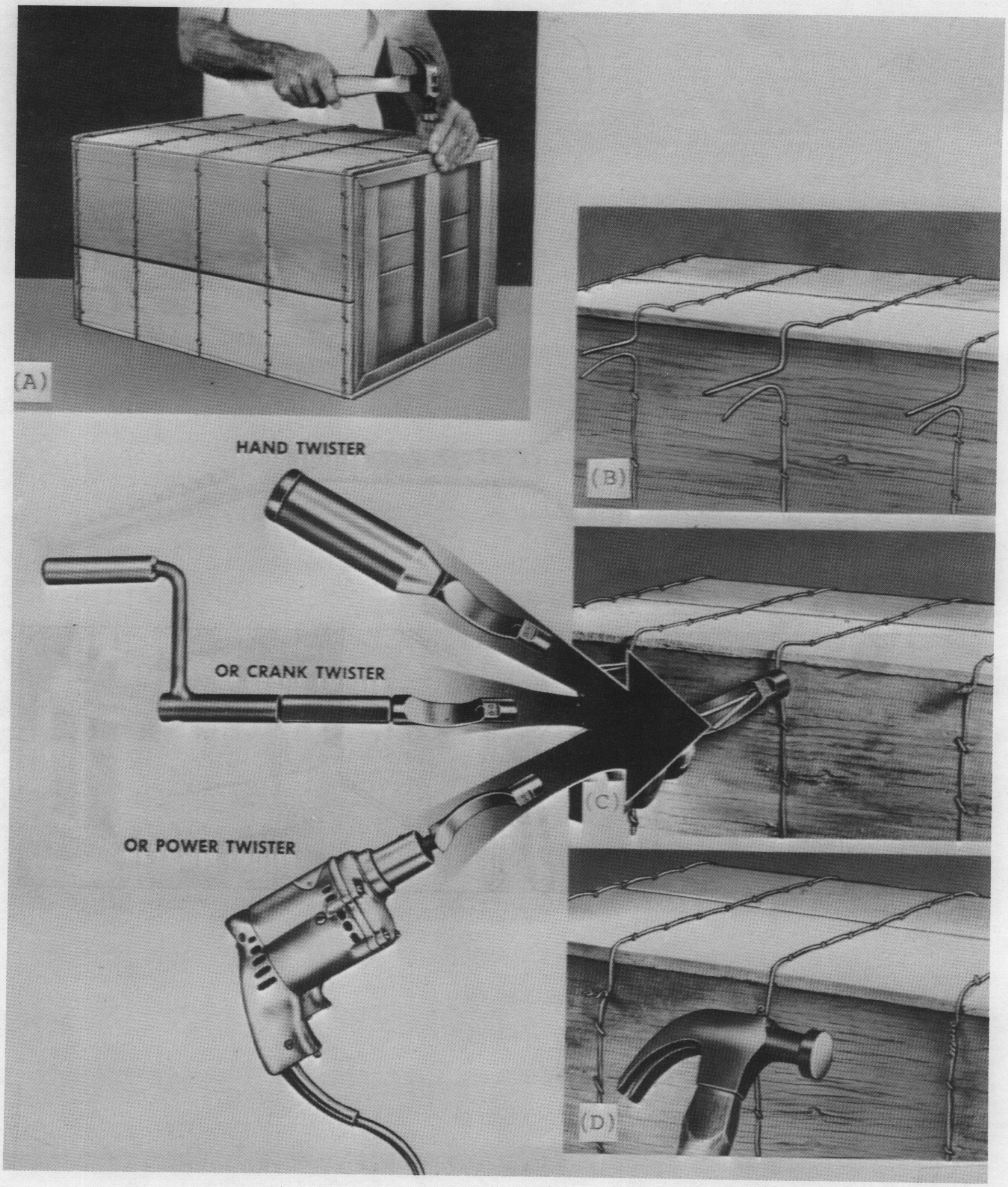


Fig. 10-26. Closing of Style 1 Wirebound Wooden Boxes

463-524 O - 72 - 14

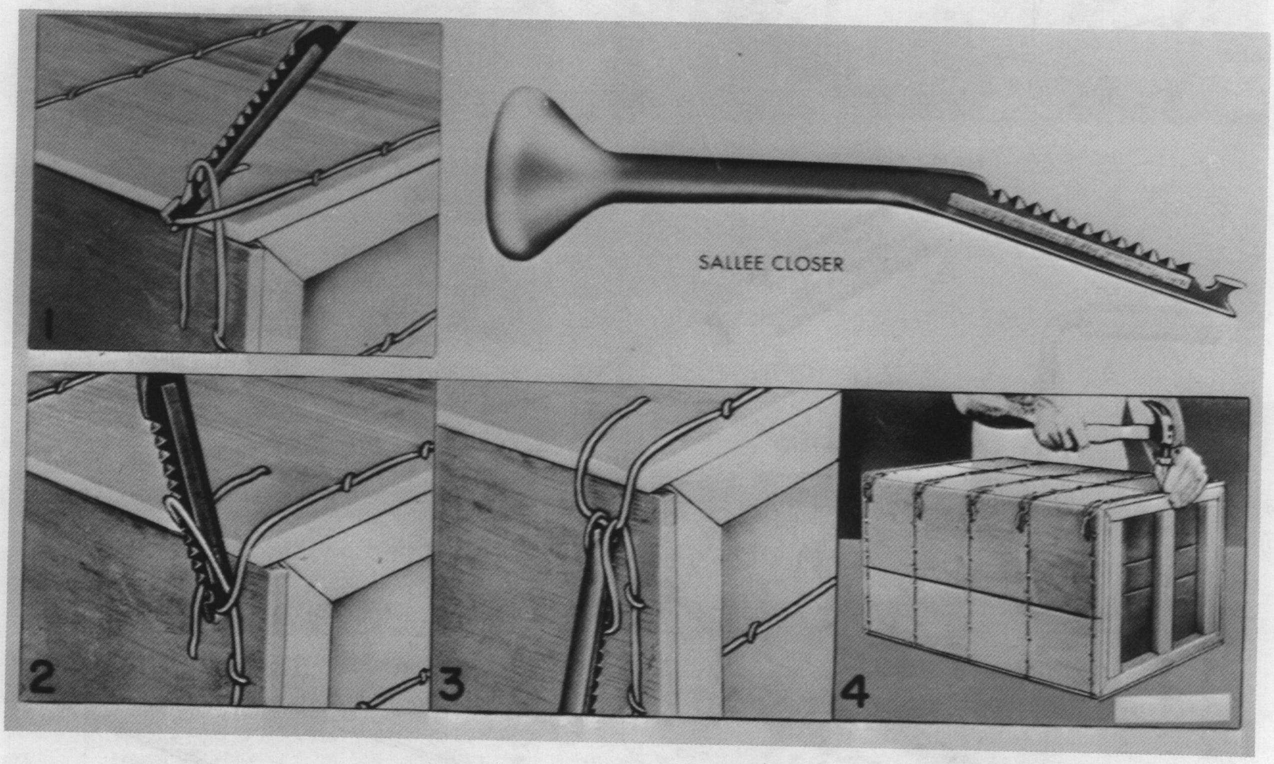


Fig. 10-27. Closing of Style 2 and Style 3 Wirebound Wooden Boxes

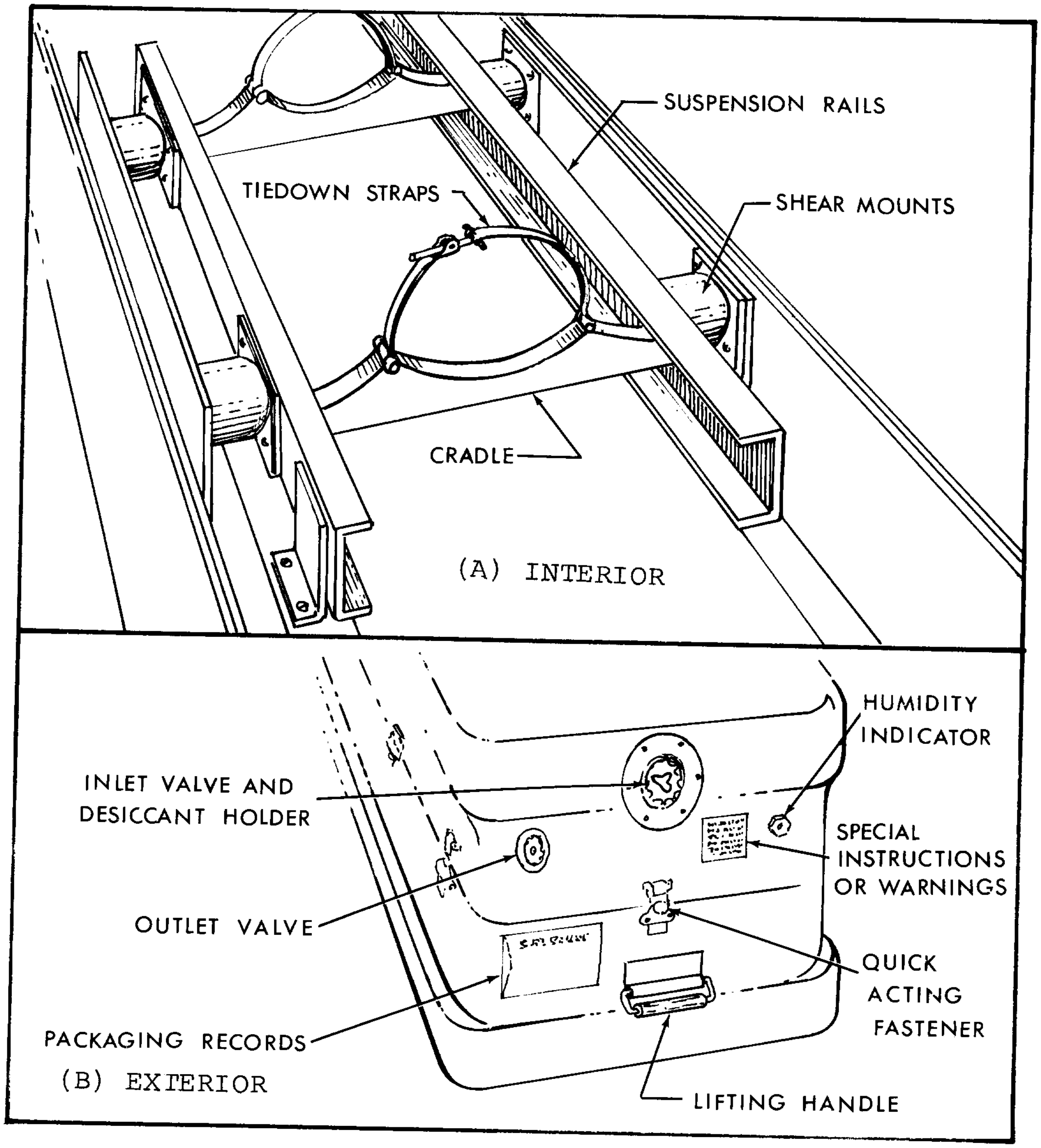


Fig. 10-28. Features of Reusable Containers

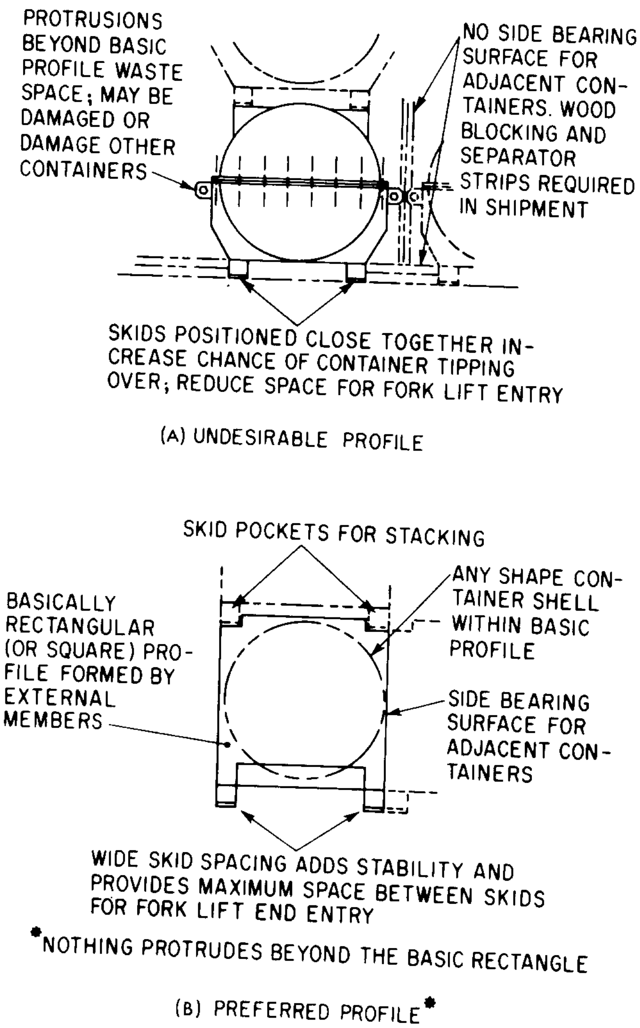


Fig. 10-29. Undesirable and Preferred End Profiles for Stacking Containers

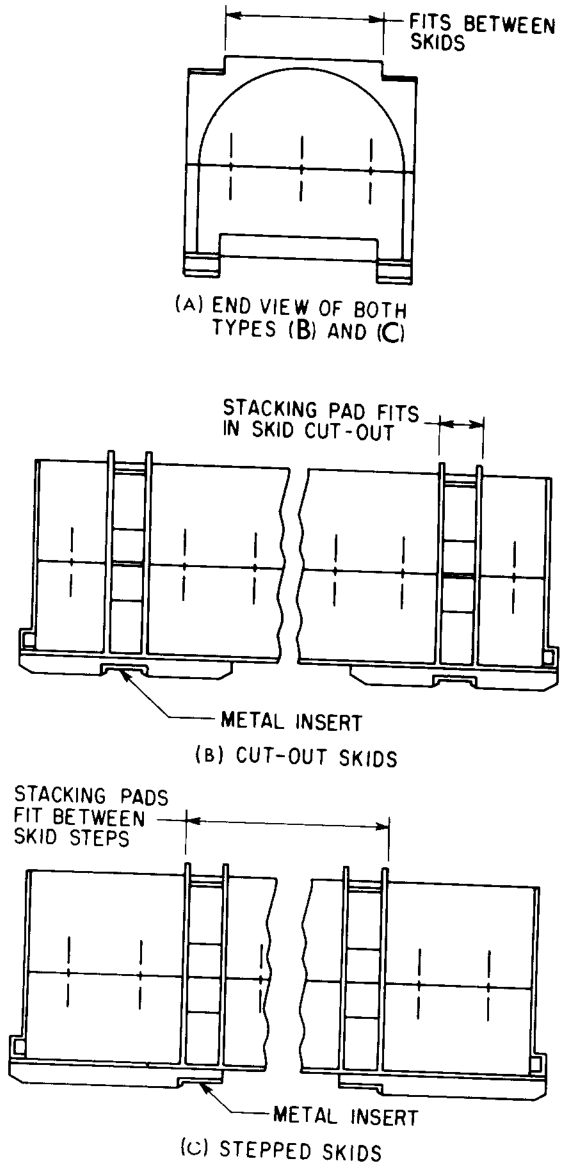


Fig. 10-30. Positioning and Alignment Features for Stacking Containers

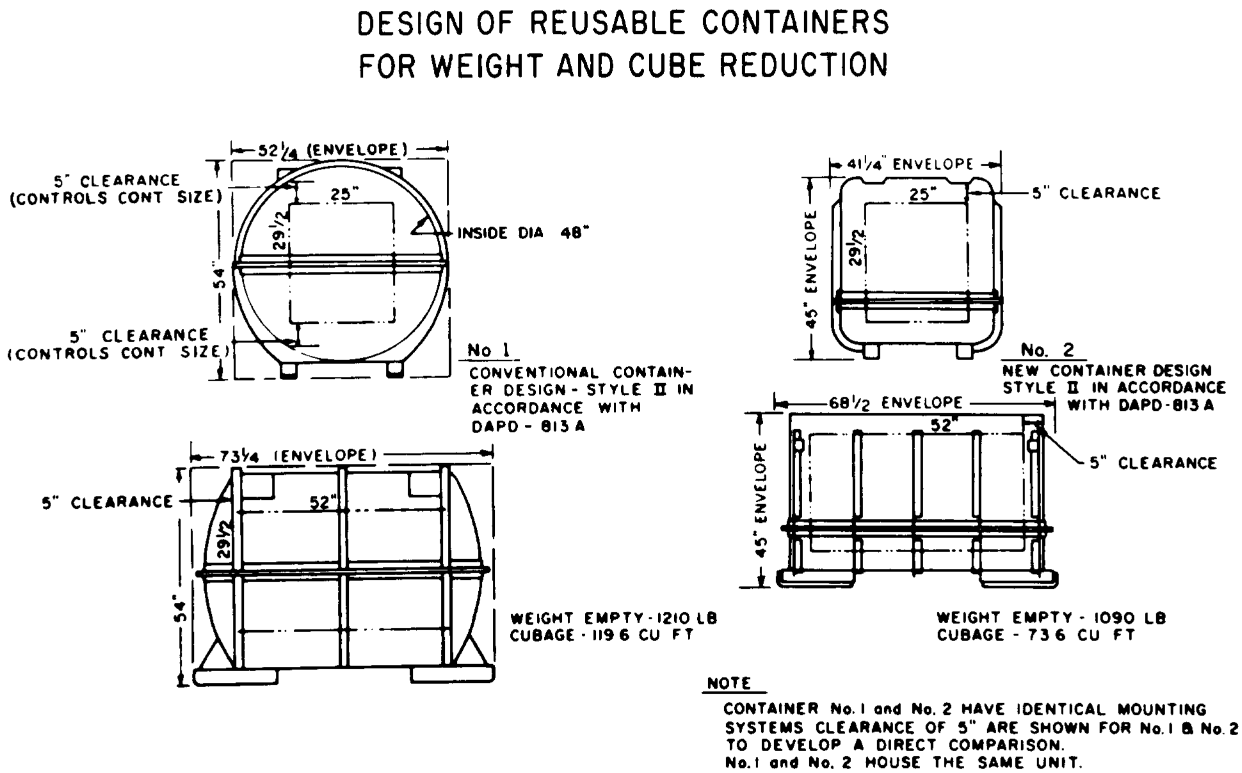


Fig. 10-31. Reusable Exterior Containers

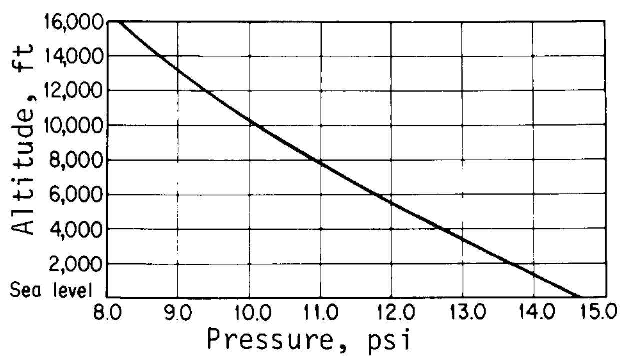


Fig. 10-32. Atmospheric Pressure as a Function of Altitude

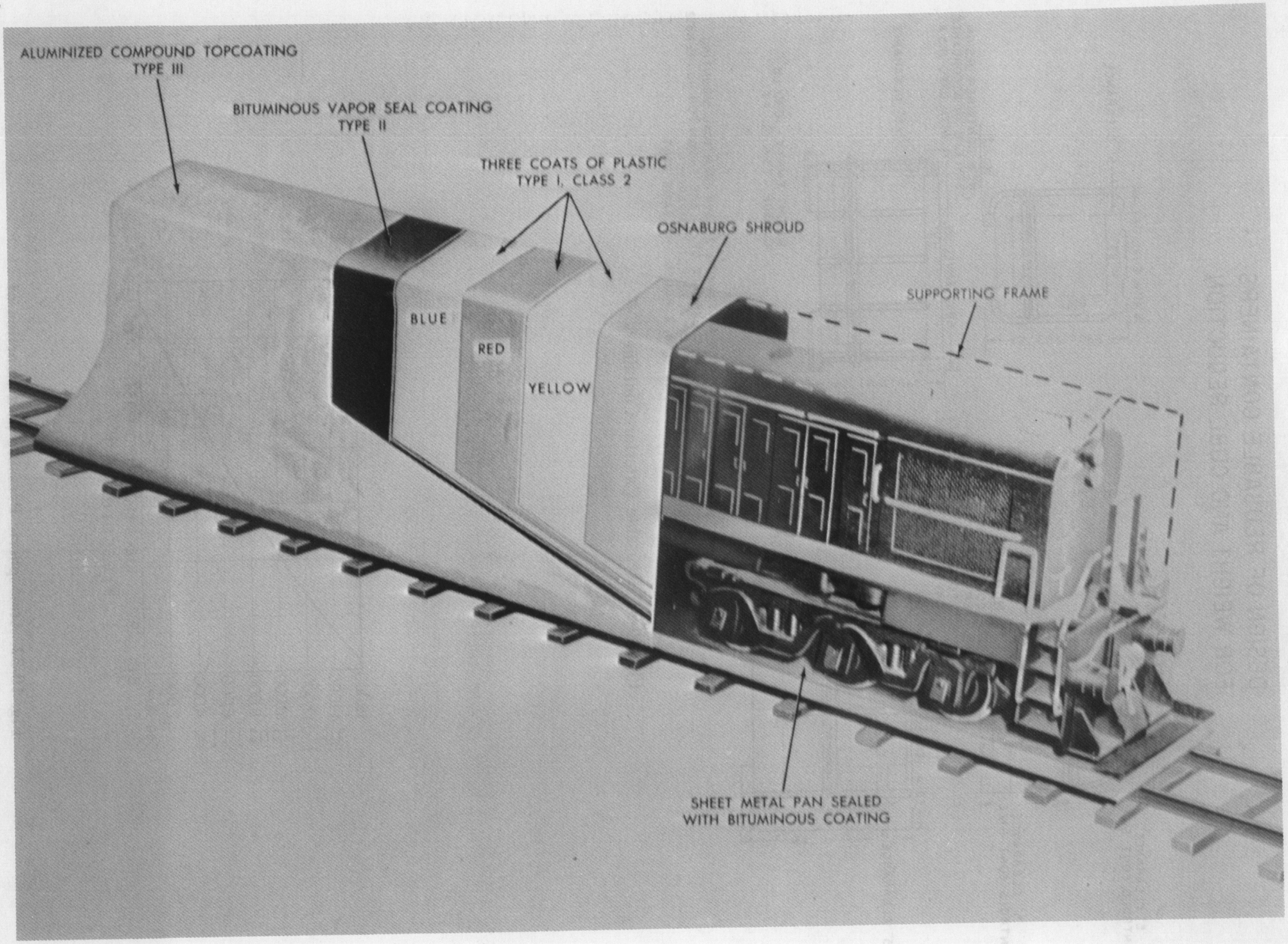


Fig. 10-33. Application of Strippable Films to Locomotive

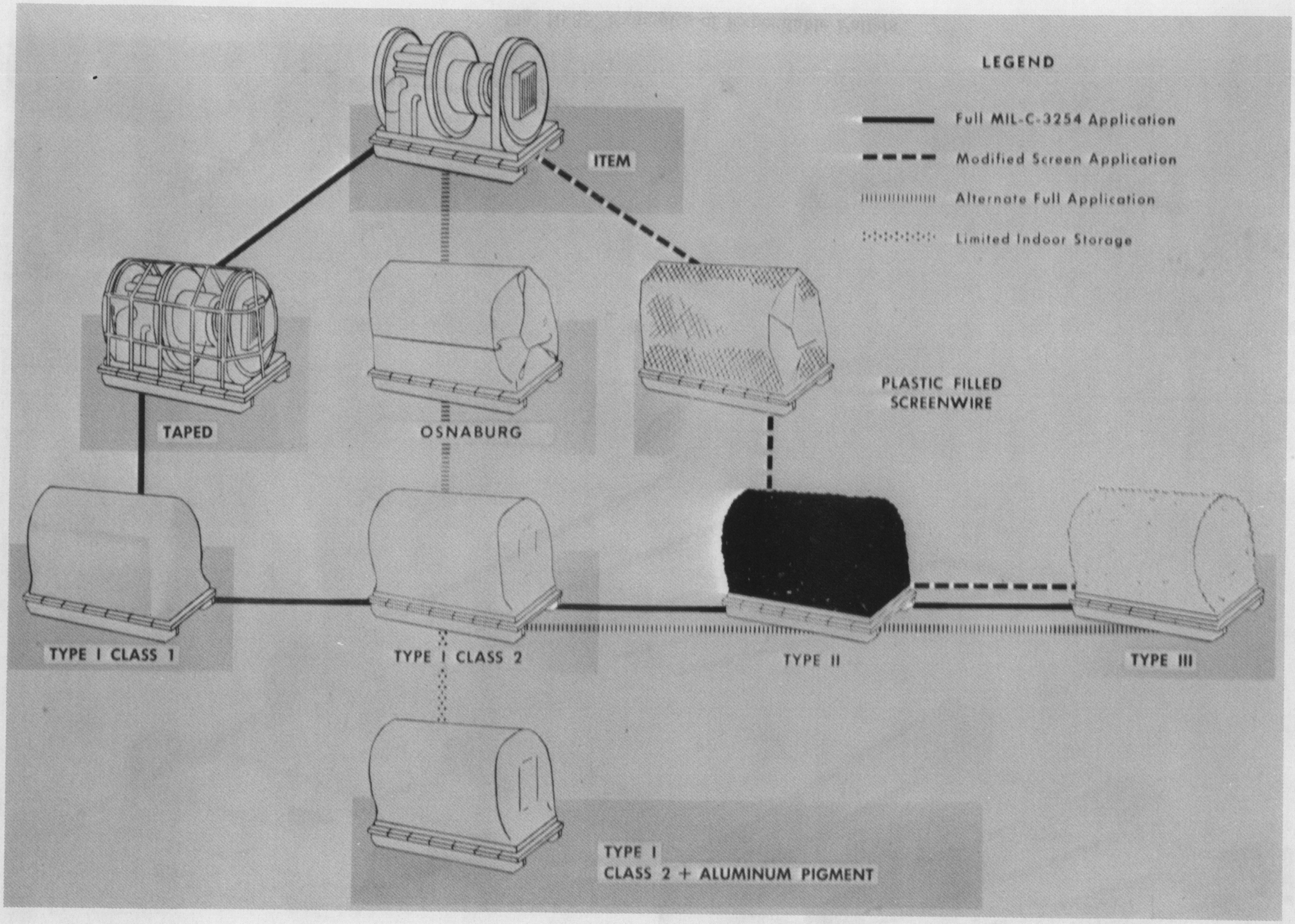


Fig. 10-34. Sprayable, Strippable Film Application

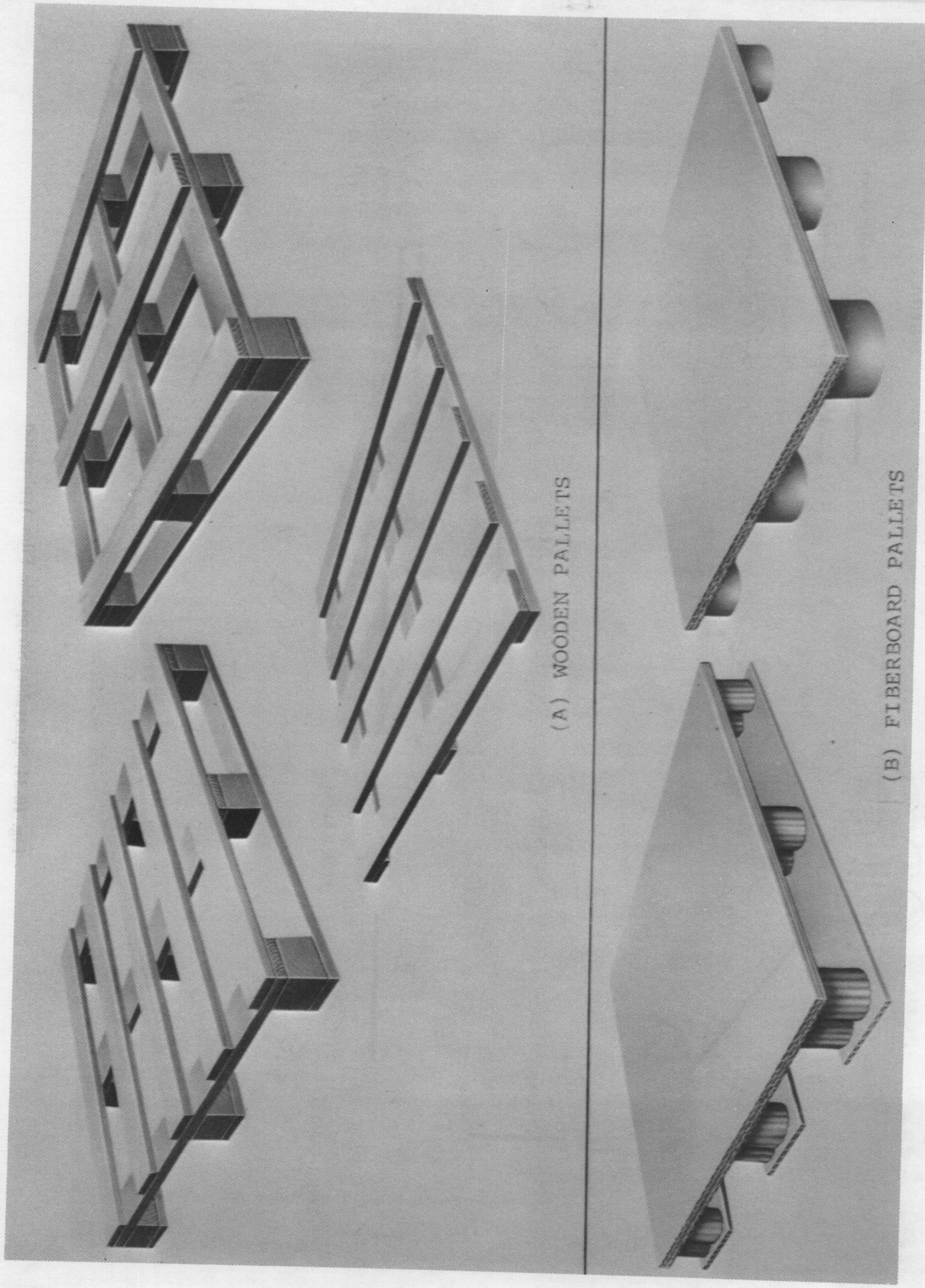


Fig. 10-35. Examples of Expendable Pallets

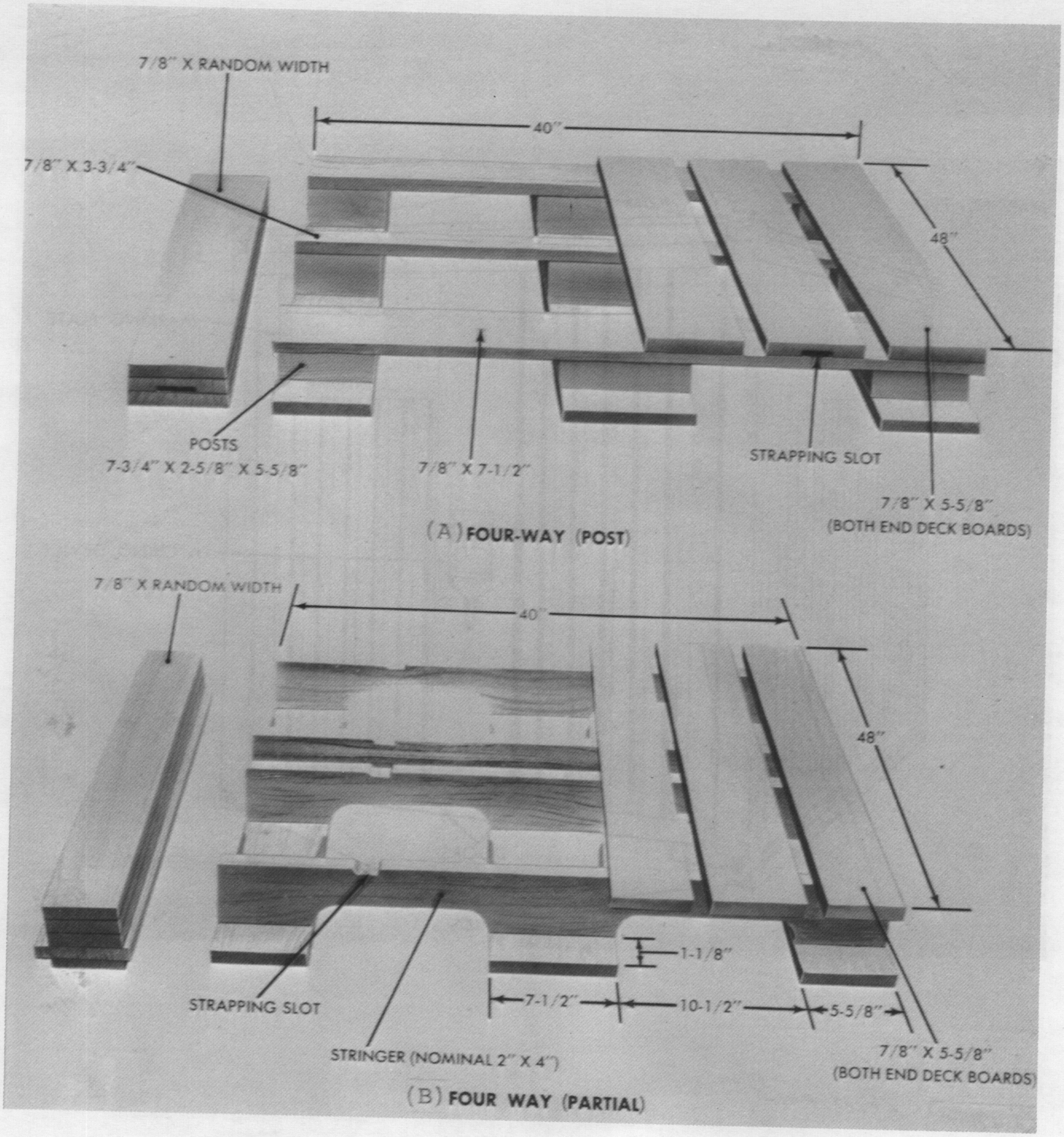


Fig. 10-36. Construction of 4-way Entry Pallets

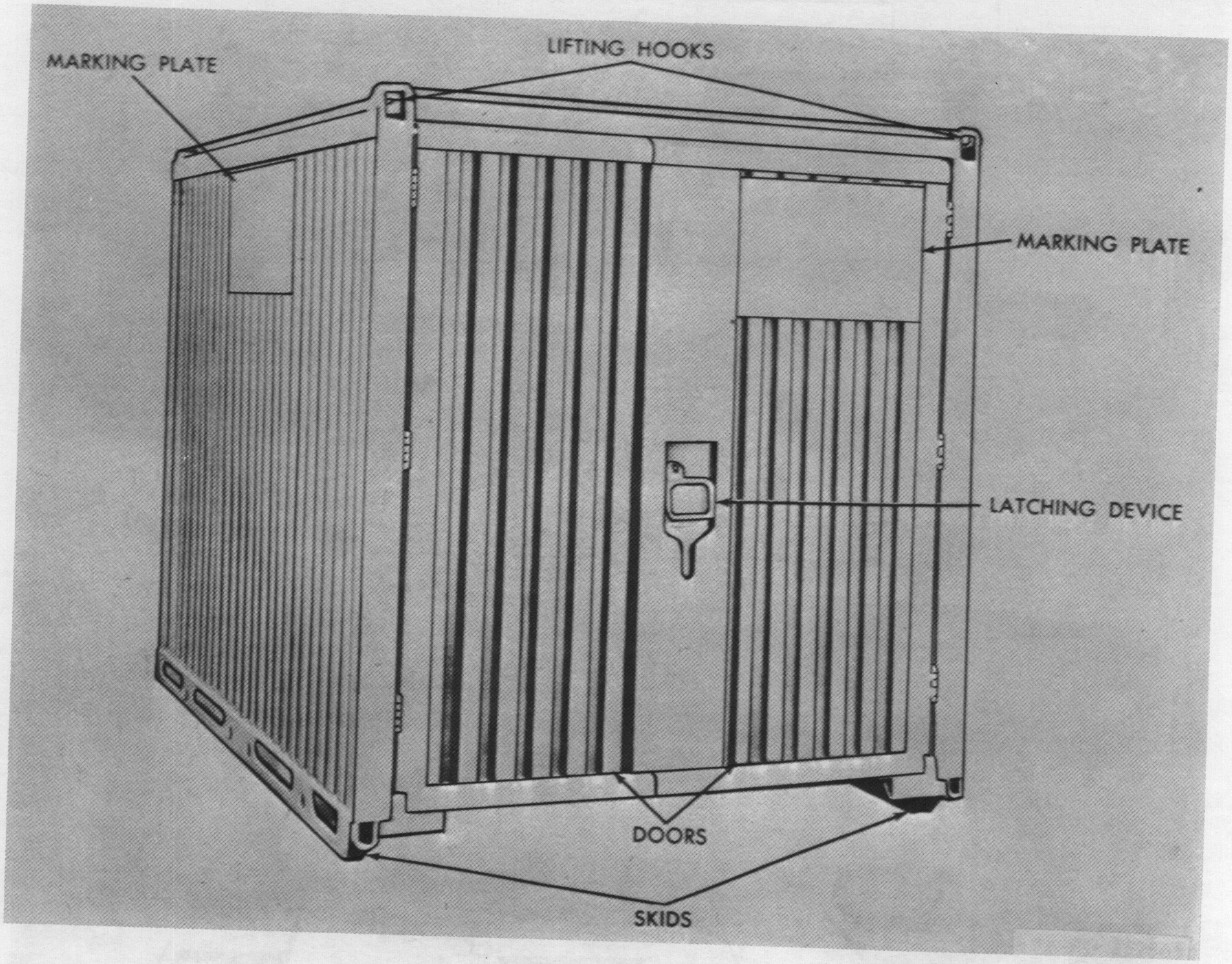


Fig. 10-37. Reusable Metal Shipping Box (CONEX)

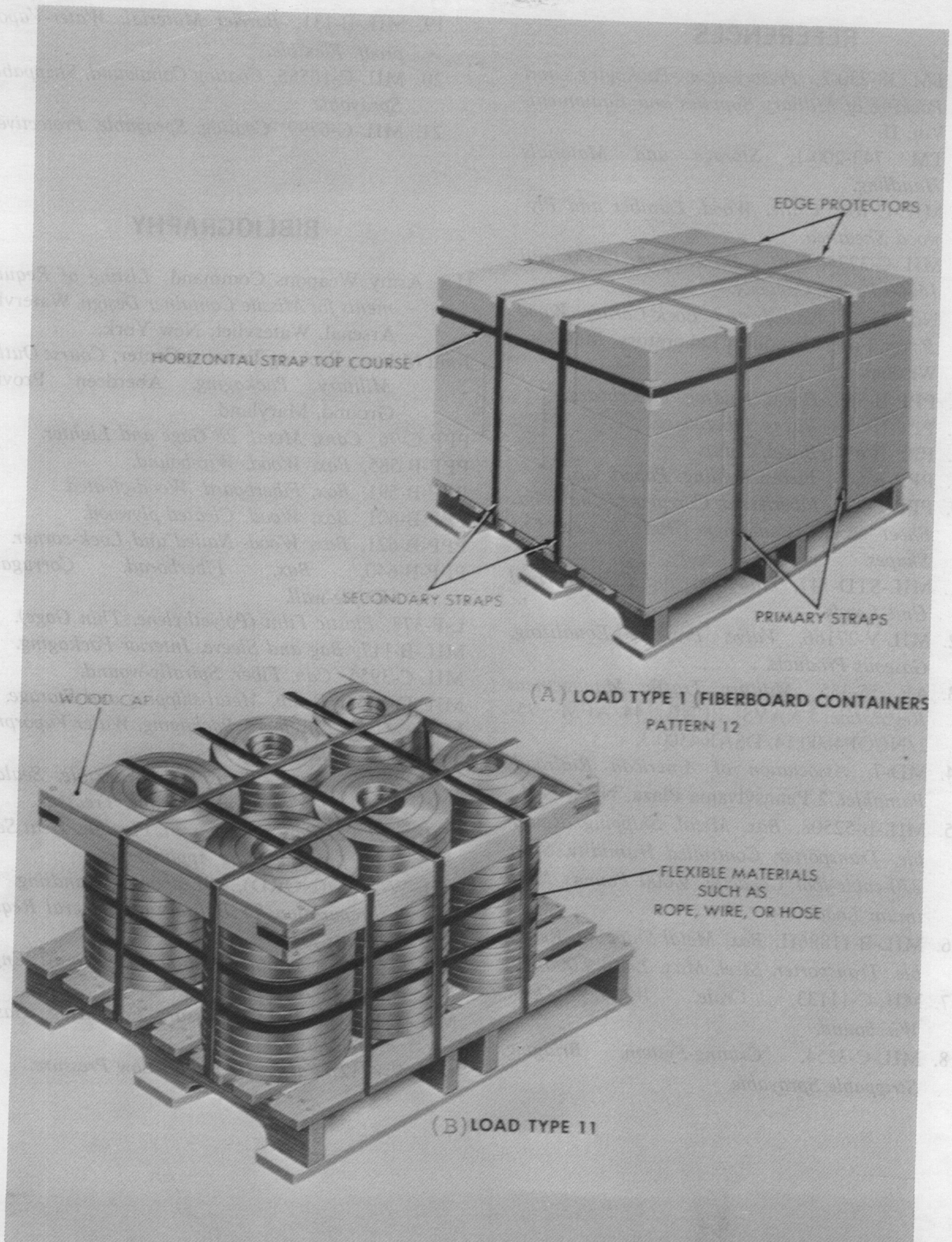


Fig. 10-38. Examples of Palletized Loads

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2. TM 743-200-1, *Storage and Materials Handling.*
3. MIL-C-104, *Crate, Wood, Lumber and Plywood Sheathed.*
4. MIL-C-3774, *Crates, Wood Open, 12000- and 16000-Pound Capacity.*
5. No. 2129, *Nailed and Lock-Corner Wood Boxes,* Forest Products Laboratory, Madison, Wisconsin.
6. PPP-B-566, *Boxes, Folding, Paperboard.*
7. PPP-B-636, *Boxes, Fiberboard.*
8. PPP-B-676, *Boxes, Setup.*
9. PPP-B-665, *Boxes, Folding, Paperboard.*
10. PPP-F-320, *Fiberboard; Corrugated and Solid, Sheet Stock (Container Graded), and Cut Shapes.*
11. MIL-STD-147, *Palletized and Containerized Unit Loads.*
12. MIL-V-27166, *Valve, Pressure Equalizing, Gaseous Products.*
13. AR 55-355, *Military Traffic Management Regulation,* NAVSUPPUB 44/AFM 75-2/NCOP4600.14/DSAR4500.3.
14. MD-7, *Association of American Railroads Pamphlet,* 2 Pennsylvania Plaza, N.Y., N.Y.
15. MIL-B-52508, *Box, Metal, Shipping: Reusable, Transporter, Controlled Humidity, Steel, 270-cubic-foot Capacity, 9,000 Pounds Maximum Load.*
16. MIL-B-11886H, *Box, Metal Shipping, Reusable, Transporter, Steel, Max. Load 9,000 lb.*
17. MIL-C-11133, *Crate, Wood, Open, Wirebound.*
18. MIL-C-3254, *Crating-System, Bridging, Strippable Sprayable.*
19. MIL-B-131, *Barrier Material; Water-Vaporproof, Flexible.*
20. MIL-C-16555, *Coating Compound, Strippable, Sprayable.*
21. MIL-C-6799, *Coating, Sprayable, Protective.*

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PPP-B-585, *Box, Wood, Wirebound.*

PPP-B-591, *Box, Fiberboard, Wood-cleated.*

PPP-B-601, *Box, Wood, Cleated-plywood.*

PPP-B-621, *Box, Wood, Nailed and Lock-corner.*

PPP-B-640, *Box, Fiberborad, Corrugated, Triple-wall.*

L-P-378, *Plastic Film (Polyethylene, Thin Gage).*

MIL-B-117, *Bag and Sleeve, Interior Packaging.*

MIL-C-3955, *Can, Fiber, Spirally-wound.*

MIL-D-6054, *Drum, Metal-shipping and Storage.*

MIL-E-6060, *Envelopes, Packaging, Water Vaporproof, Flexible.*

MIL-B-22020, *Bag, Transparent, Flexible, Sealable, Volatile Corrosion Inhibitor, Treated.*

MIL-B-22205, *Bag, Transparent, Flexible, Heat Sealable for Packaging Applications.*

MIL-W-21927(NORD), *Weapons; Handling and Preparation for Delivery of; General Requirements for.*

MIL-C-5584, *Containers, Shipping, Aircraft Engine, Metal, Reusable.*

MIL-V-17203, *Valves, Pressure Equalizing, Gaseous Products.*

MIL-V-8712, *Valve, Air Relief, Low Pressure.*

CHAPTER 11

FASTENERS AND CLOSURES

11-1 USES AND TYPES

Typical fasteners include links, hooks, clinches, rivets, clamps, ties, bolts, screws, nails, and tacks. Typical closures include latches, straps, and binders.

Fasteners and closures are used in the following ways in packaging:

a. To fabricate containers

b. To secure items within containers

c. To close containers

d. To secure shipping containers to skids and pallets.

Although the packaging engineer is rarely concerned directly with these operations, his design of packages is affected by the adequacy of these operations. A knowledge of the properties of the common methods of fastening and closure is relevant to package design and to selection of containers. Each military container specification has a section or appendix devoted to closure. It is important that the instructions contained in these publications be observed.

Fastening and closing devices for the containers discussed in Chapter 9 are used in the following manner:

a. *Wirebound wooden boxes:* All styles are closed by joining the ends of the binding wire, and may be reinforced with strapping.

b. *Cleated plywood boxes:* Nailed.

c. *Nailed and lock-corner wooden boxes:* Nailed and strapped.

d. *Wooden boxes:* Strapped for overseas.

e. *Wooden crates:* Nailed and bolted construction. Assembled with straps.

f. *Lumber and plywood sheathed crates:* Nailed and bolted.

g. *Wood-cleated fiberboard boxes:* Strapped.

i. *Triple wall corrugated fiberboard boxes:* Tapes and adhesives.

j. *Metal cans:* Closures such as screw or lug caps, friction tops, hermetic seals, or slip covers depending on contents. Cans with screw or lug caps or friction tops may be reusable.

k. *Pails:* Friction tops, slip covers, and lug or bolt rings.

l. *Steel shipping containers:* Lug-type locking rings.

This chapter covers the following types of devices:

a. Nails

b. Screws

c. Corrugated fasteners

d. Bolts

e. Strapping

f. Staples and stitching

g. Twine

h. Tape

Tapes and adhesives which are also used extensively for fastening are mentioned only briefly in this chapter since they are covered in more detail in Chapter 12.

11-2 FASTENERS

The fabrication of a satisfactory wooden container depends on two primary factors:

(1) Selection of the proper sizes of lumber

(2) Selection and proper use of the various methods of fastening the selected lumber together to form the container.

Boxes are assembled with nails, screws, and corrugated fasteners. Screws and nails may be used alternatively, although nails are preferred for most applications. Screws, however, are sometimes particularly desirable when the contents of the box require check, test, relubrication, or other inspection during storage. In such cases, screws should be substituted for nails for the top of the box.

11-2.1 NAILING

Nails are the most common fastenings for boxes as well as for blocks and braces. Common types of nails available and information on these different types are given in Tables 11-1 through 11-15. Also see Figs. 11-1 and 11-2.

11-2.1.1 Box Construction Defects

Tests of packing boxes indicate that the most common defect in box construction is inadequate nailing. Attempts to strengthen boxes by the use of thicker lumber without regard for nailing often waste material without achieving the desired results.

11-2.1.2 Nailing Techniques

The following general characteristics of nails should be especially noted in box construction:

a. Cement-coated or chemically etched nails have a holding power considerably greater than smooth nails. About 25 percent more nails of the same size are needed when smooth nails are used in place of cement-coated or chemically etched nails.

b. The sizes of nails for fastening sides, tops, and bottom to end and cleats are determined by the types of wood used as well as by the size of the members (Fig. 11-1, and Tables 11-1 and 11-2).

c. The nails commonly used in box fabrication are coolers, corkers, sinkers, standard box, or common (Tables 11-3 to 11-7). The box and cooler nails have thin heads and shanks, whereas the other nails are thick-shanked. Also in use are mechanically deformed nails, as shown in Table 11-8, designed for added holding power.

d. A slender nail is likely to hold better than a thick nail under the repeated shocks and constant weaving action to which boxes are subjected in shipment because the slender nail bends near the surface of the pieces joined without loosening the friction grip of the nail shank.

e. Nails spaced closely in a line parallel to the grain induce splitting. The first and last nails should be spaced one-half of the specified spacing from the ends of the nailing edge, but not less than 3/4 in. If it is necessary to exceed this spacing because of small knots or checks in the nailing end, or because of the location of joints between boards, the distance between any two adjacent nails should not be greater than one and one-half times the prescribed spacing.

f. If the desired nail size is not available, one size smaller may be used and the nails should be spaced 1/4 in. closer than is required for the size of the nail originally specified.

g. At least two nails should be used in each end of each board.

h. Wherever cleats are used in the end construction, approximately one-half of the nails used to secure lengthwise boards, joining top, bottom, or sides to cleat edge should be driven into the end and the remainder into the cleat (Tables 11-1, 11-2, and 11-9 to 11-15).

i. All nails should be so driven that no part projects above the surface of the wood. Also, no nail should be overdriven more than one-eighth the thickness of the piece because this tends to crush the wood around the head, thus weakening the joint.

j. The resistance to withdrawal is higher when nails are driven into the side grain than when driven into the end grain of the wood, i.e., facenailed (Fig. 11-2).

k. When nailing cleats or battens to the sides, top, or bottom; nails should pass through both pieces and be clinched not less than 1/8 in. Clinching, in effect, makes the nail act as a rivet, thus increasing its resistance to withdrawal. Either cement-coated, chemically etched, or bright uncoated nails may be used if they are to be clinched.

11-2.1.3 Blocking and Bracing

Nails used in blocking and bracing should be cement-coated or chemically etched, particularly when the nails cannot be clinched. Standard cooler, sinker, and box nails are particularly well suited for use with interior packing. They are relatively slender, can be driven into the denser woods, withstand shocks well, and the heads do not break off or pull through the wood easily. Because of the larger head, clout nails are recommended where plywood of 1/2 in. or less is used.

Whenever possible, nails should be applied so that they are subjected to forces of lateral displacement rather than direct withdrawal; i.e., they should be applied so that the directon of the nails will be perpendicular to the direction of the load rather than in line with the direction of the load. If the withdrawal resistance of the nail is known, it is possible to determine the number of nails required to hold a load of a given weight.

11-2.2 CORRUGATED FASTENERS

When it is necessary to use two or more pieces to form the sides, top, or bottom of a box, the pieces may be butt-joined and fastened together with corrugated fasteners. Although corrugated fasteners contribute lit-

tle to the strength of the box, especially where the moisture content of the wood is high, they have two main uses: (1) during manufacture, they facilitate handling; and (2) during shipment, they discourage pilferers from cutting nails and sliding intermediate boards out of the way to gain access to the contents. When used, the length of the corrugated fasteners should never exceed three-quarters of the thickness of the piece being fastened.

11-2.3 BOLTS, SCREWS, AND RIVETS

The selection of proper fastenings for any given job requires close examination of all specifications and limitations, for example:

a. *Type of Service:* Will the assembly be subject to vibration, impact loads, tension or shear stresses, or a combination of these? Is repeated disassembly required? Self-tapping screws must not be used unless fastening is of a permanent nature. Will the fastener also function as a locator, as in the case of a stud? Will the fastening function satisfactorily unaided, or must dowel pins, keys, or other devices also be used?

b. *Materials Being Joined.* Will rivets, self-tapping screws, nut plates, clinch nuts, and through bolts be used to assemble sheet-metal parts? Steel fasteners for nonferrous metals may result in electrolysis and corrosion of the metals. Corrosion can be confined to an insert without damage to a screw used with it. Inserts in plastics or soft metals protect against thread damage when frequent disassembly is required.

c. *Economy.* It is not economical to use too large, too small, or too many fasteners. Lowered product quality and safety can result from too few or too small fasteners.

Some common types of bolts, screws, and nuts are shown in Figs. 11-3 and 11-4.

Self-tapping, self-piercing, and drive screws have wide application in sheetmetal work, wood, and plastics. A lead hole must be provided for the self-tapping and drive types, but tapping is eliminated. The self-piercing type is hammered through the work material and the protruding end, if any, is turned down or machined off. The wide variety of these screws available is shown in Fig. 11-4.

Lock nuts and lock washers, properly applied, prevent loosening of the assembly under vibration or jarring. The locking action is accomplished by squeezing, gripping, or jamming against the bolt threads.

11-2.3.1 Materials for Bolts, Screws, and Nuts

The principal metals used for bolts, screws, and nuts–with their chief qualifications–are listed in Table 11-16. Nylon, polyethylene, and other plastic nuts, screws, and various fasteners are light in weight, immune to corrosion and moisture, tough, resilient, have good dielectric strength, and for many applications, can do a job metal fasteners cannot accomplish. The plastic fasteners are generally at a disadvantage when (1) fastener cost alone is important, (2) requirements of stress and shear are high, and (3) temperature conditions are higher than 350°F.

11-2.3.2 Holding Power of Bolts and Nuts

A common nut drilled out so that it contains 50 percent of a full-depth thread will break the bolt before it will strip. A full-depth thread is only about 5 percent stronger than a 75 percent depth of thread, yet it requires three times the power to tap. Because it provides maximum strength for safety and economical tapping, a 75 percent depth of thread is recommended.

11-2.3.3 Strength of Bolted Joints

The strength of a joint depends upon the amount of residual tension left in the bolt after the wrench is removed. While it is necessary to have a bolt strong enough to carry the required loads, the element that makes a joint strong is residual tension or preload.

11-2.4 SCREWS

Screws are most commonly used on reusable containers, or if inspection of the contents is anticipated. Data on various screws are provided in Tables 11-17 to 11-24.

11-2.5 BOLTS

Bolts are of two basic types:

(1) Those which are driven into predrilled holes

(2) Those which require a nut and washer for securing.

The type selected will depend on the need for easy removal. Bolts commonly used for blocking and bracing are step bolts, carriage bolts, and machine bolts (Fig. 11-3). Step bolts are preferred because of their larger head diameter. U- or J-bolts are used for special conditions where regular bolts cannot be applied. Tie rods and J-bolts are actually extended bolts–applied in

pairs, vertically or diagonally–and are used where standard length bolts would not apply.

The following general precautions should be observed when bolts are used:

a. When using holes in the item for attachment, the bolt should be the same size as the hole in the item. For critical assembly fittings, however, smaller bolts and bushings should be used to protect the precision tolerances. Lag screws or lag bolts should not be used in either instance.

b. When an item is bolted to the base, the bolt head should be on the outside of the container base or the bottom of the auxiliary base and should bear against a wide washer to decrease the possibility of pulling through the wood.

c. When skids are used, whenever possible the bolts should extend through the skids and be countersunk in the outer surface of the skid.

d. When the item has strong frame members fairly close to the faces of the container, U- or J-bolts may be used to advantage (Fig. 11-5).

e. Tie rods serve as extended bolts when used to secure items in the container and should be used in the same general manner as other types of bolts. They should be placed vertically or used diagonally in pairs.

f. Many items have attachment points that provide facilities for bolting, but the points are not located on a regular base that can be fastened directly to the container. Where U- or J-bolts or tie rods can be used, especially constructed brackets, sleeves, or frames made entirely of metal, wood, or a combination of these, can be used to act as intermediate connections between the item and the container. To function satisfactorily, frames must be properly designed to permit ample fastening of the frame to both the item and the container, or in the case of sleeves, to fit the interior of the container snugly.

Tables 11-25 through 11-28 and 11-32 list various factors useful in determining sizes and types of bolts to be used for specific applications. Fig. 11-6 illustrates "T" nuts that can be used when fabricating reusable panel boxes.

11-2.6 STRAPPING

Metal strapping is used as reinforcement for blocking and bracing, and most commonly as reinforcement for exterior containers. Only tempered, high tensile strength, flat steel or round wire strapping should be used for container reinforcement, except in limited instances such as reinforcing a crate corner where an annealed nail-on-type flat steel strapping is usually used. (See Tables 11-29 through 11-31 and Figs. 11-7 and 11-8.) For overseas shipment, bare metal strapping should not be used because of its lack of corrosion resistance.

Nonmetallic strapping may be used for domestic class fiberboard boxes under the limitations and conditions specified in PPP-B-636 and for fiberboard unit loads under the conditions and limitations specified in MIL-T-35078.

11-2.6.1 Reinforcement for Blocking and Bracing

The use of strapping to tie down an item to the base or other faces of the container is often the only convenient procedure that can be used. Strapping may be either flat steel or round wire. Both kinds of strapping are preferably tensioned and sealed with specially designed tools. If this is not possible, flat strapping can be held in place with anchor plates and round wire strapping with special drive screws and staples. General precautions on the use of metal strapping, which apply to both flat steel and round wire, are:

a. Where possible, the item and the support must be completely encircled. When it is impossible to do this, the two ends of the metal strapping must be anchored.

b. One-piece straps should be used wherever possible.

c. Straps should be placed only on those strong parts of the item that can withstand the impact load and weight of the item.

d. Where strapping passes over a sharp edge of the item, corner protectors may be required to protect the strapping from fracturing.

e. Protecting materials should be used between the item and the strap if the strap might harm or scratch the item.

f. Strapping should be arranged on the container, where possible, to further reinforce blocking and bracing or anchoring of the item within the container.

g. Annealed strapping should be used only for lightweight items because it stretches readily.

11-2.6.2 Reinforcement of Exterior Containers

The following general precautions are advisable:

a. Use strapping of an acceptable type conforming to the appropriate Military Specification.

b. Use strapping of correct size and strength.

c. Use the correct number of straps depending

upon the weight, contents, style of container, as specified in the appropriate container specification.

d. Locate the strapping correctly.

e. Staple straps to boards or cleats when thickness is 5/8 in. or more. Staples should be cement-coated or chemically etched and should not be spaced more than 6 in. apart. Over-driving of the staples should be avoided since any creasing of the strap might weaken it, and any fracturing of the strap coating might permit corrosion.

f. All straps must be applied at right angles to the edges of the box over which they pass.

g. Use correct tensioning tools designed for particular type and style of strap.

h. Apply sufficient tension so that straps will sink into edges of container but do not over-tension to the point that the strapping is weakened or the container damaged. Conversely, the straps must not be so loose as to engage another box and interfere with the handling.

i. Avoid applying straps over voids where they will be a hazard to handling personnel and where they will not add to the strength of the container.

j. Do not apply straps on the bottom surface of skids. Notch the skid for the straps or place the straps so that they are between the skids.

k. Strap the boxes just before shipping since most boxes shrink during long periods of storage. At the time of shipment any previously applied straps should be examined, and if found to be loose, the containers should be restrapped.

11-2.7 WOOD FASTENINGS

Wood fastenings used with bolts are suitable for many different types of applications. The withdrawal load of a round drift bolt from the side grain of seasoned wood is given by the formula:

$$P = 6000\, G^2 D \tag{11-1}$$

where

P = ultimate withdrawal resistance per lineal inch of penetration

G = specific gravity of wood

D = shank diameter, in.

11-2.8 STAPLING AND STITCHING

Wire stitches and staples are widely used in fabricating wooden containers, but only rarely for the fastening and closure of the containers at the point of use.

11-2.9 TWINE

The principal use of twine is in the baling of items or products that can be packaged by consolidating small items or compressing bulky items into a single, compact unit for shipment–e.g., tents, bedding, tarpaulins, clothing, or any other soft compressible item. The outer wrap or cover usually consists of burlap or Osnaburg cloth in the form of tubes, bags, or sheets. Closures are made by sewing, strapping, or tying. If the closure is made by sewing, or the tying is by use of twine, then the closure will be accomplished by securely sewing or tying with jute or cotton twine (Ref. 6).

11-3 CLOSURES

The use and considerations for the function of tapes and adhesives as closures are given in Chapter 12. Adhesives are most economical to use depending on the type of sealing equipment used. Use of an adhesive depends primarily upon the following factors:

a. Type of surface

b. Rate of setting, which depends upon the speed of application as well as the time under compression and tension factors of the container

c. Specific end-use requirements such as ease of opening.

Tapes are classified by the type of adhesive used:

a. *Gummed tapes.* Water- or solvent-activated adhesive.

b. *Pressure-sensitive tapes.* Use of an adhesive which adheres under pressure.

c. *Heat-activated tapes.* Heat and pressure used to provide a bond.

For additional data on tapes, see Refs. 1, 2, and 3.

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TABLE 11-1
NAIL SIZE FOR ASSEMBLY OF SIDES, TOP, AND BOTTOM TO ENDS OR CLEATS (WOODEN BOXES)[6]

Species of wood		Thickness of ends or cleats to which sides, tops and bottoms are nailed, in										
	Exceeding	---	7/16	1/2	9/16	5/8	11/16	13/16	7/8	1	1-1/8	1-1/4
	Not exceeding	7/16	1/2	9/16	5/8	11/16	13/16	7/8	1	1-1/8	1-1/4	---
Group I		4	5	5	6	7	8	8	9	9	10	12
Group II		4	4	5	5	6	7	7	8	9	9	12
Group III		3	4	4	5	5	6	7	7	8	9	10
Group IV		3	3	4	4	4	5	6	7	8	8	9

NOTE: Nail sizes are in pennyweights.

TABLE 11-2
DOMESTIC TYPES, SIZES, AND SPACING FOR FASTENING TOGETHER ADJACENT CLEATED PANELS[6]

Cleats, thickness in.	Nails, Spacing, maximum in.	Size of Nails for Wood Groups (1)		
		I and II Penny	III Penny	IV Penny
9/16 or 5/8. . . .	5	6	6	5
11/16 or 3/4 . . .	4	7	7	6
13/16 or 7/8 . . .	3	8	7	7

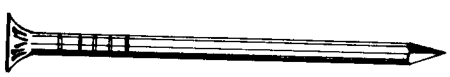
(1) If the nail protrudes through the last edge cleat or if it splits the cleat, then the next smaller size penny nail shall be used.

TABLE 11-3
CEMENT-COATED STANDARD NAILS (COOLERS)

Flat head, diamond point

Size	Length In.	Diameter In.	Head In.	No. / lb
2d	1	0.0625	11/64	1,110
3d	1-1/8	.067	3/16	839
4d	1-3/8	.080	7/32	493
5d	1-5/8	.086	15/64	366
6d	1-7/8	.0915	1/4	278
7d	2-1/8	.099	17/64	212
8d	2-3/8	.113	9/32	144
9d	2-5/8	.113	9/32	131
10d	2-7/8	.1205	19/64	105

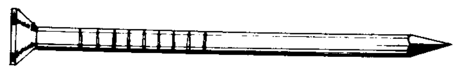
TABLE 11-4
CEMENT-COATED COUNTERSUNK RAILROAD NAILS (CORKERS)



Flat countersunk head, diamond point

Size	Length In.	Diameter In.	Head In.	No. /lb
2d	1	.0625	5/32	1217
3d	1-1/4	.072	3/16	720
4d	1-1/2	.086	7/32	419
5d	1-5/8	.086	7/32	387
6d	1-7/8	.099	1/4	253
7d	2-1/8	.099	1/4	223
8d	2-3/8	.1205	9/32	135
9d	2-5/8	.1205	9/32	122
10d	2-7/8	.135	5/16	89
12d	3-1/8	.135	5/16	81
16d	3-3/8	.1483	11/32	62
20d	3-7/8	.177	3/8	38
30d	4-3/8	.192	13/32	29
40d	4-7/8	.207	7/16	22
50d	5-3/8	.2253	15/32	17
60d	5-7/8	.2437	1/2	13

TABLE 11-5
CEMENT-COATED COUNTERSUNK HEAD NAILS (SINKERS)



Flat countersunk head, diamond point

Size	Length In.	Diameter In.	Head In.	No. /lb
3d	1-1/8	.067	11/64	923
4d	1-3/8	.080	13/64	527
5d	1-5/8	.086	7/32	387
6d	1-7/8	.0915	15/64	293
7d	2-1/8	.099	1/4	223
8d	2-3/8	.113	17/64	153
10d	2-7/8	.1205	9/32	111
12d	3-1/8	.135	5/16	81
16d	3-1/4	.1483	11/32	64
20d	3-3/4	.177	3/8	40
30d	4-1/4	.192	13/32	30
40d	4-3/4	.207	7/16	23
60d	5-3/4	.2437	1/2	14

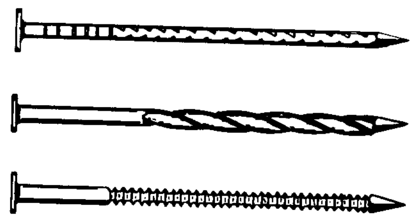
TABLE 11-6
STANDARD BOX NAILS, CEMENT-COATED

Size	Length, in.	Diameter, in.	Head, in.	No./lb
2d	1	0.058	11/64	1252
3d	1-1/8	.0625	3/16	978
4d	1-3/8	.067	13/64	680
5d	1-5/8	.072	7/32	510
6d	1-7/8	.086	1/4	315
7d	2-1/8	.086	1/4	280
8d	2-3/8	.099	17/64	190
9d	2-5/8	.099	17/64	172
10d	2-7/8	.113	19/64	119

TABLE 11-7
COMMON STEEL NAILS

Size	Length, in.	Diameter, in.	Head, in.	No./lb	
				Zinc coated	Other
2d	1	0.072	11/64	789	810
3d	1-1/4	.080	13/64	506	540
4d	1-1/2	.099	1/4	274	300
5d	1-3/4	.099	1/4	236	255
6d	2	.113	17/64	155	170
7d	2-1/4	.113	17/64	140	150
8d	2-1/2	.131	9/32	91	95
9d	2-3/4	.131	9/32	86	90
10d	3	.1483	5/16	61	65
12d	3-1/4	.1483	5/16	57	60
16d	3-1/2	.162	11/32	44	46
20d	4	.192	13/32	26	28
30d	4-1/2	.207	7/16	20	20
40d	5	.2253	15/32	17	17
50d	5-1/2	.2437	1/2	13	13
60d	6	.2625	17/32	10	10

TABLE 11-8
MECHANICALLY DEFORMED BOX NAILS–BARBED, SPIRAL, ANNULAR GROOVE



Size	Length In.	Diameter In.	Head In.	No. /lb
2d	1	.067	3/16	1010
3d	1-1/4	.076	7/32	635
4d	1-1/2	.080	7/32	473
5d	1-3/4	.080	7/32	406
6d	2	.099	17/64	236
7d	2-1/4	.099	17/64	210
8d	2-1/2	.113	19/64	145
9d	2-3/4	.113	19/64	132
10d	3	.128	5/16	94
12d	3-1/4	.128	5/16	88
16d	3-1/2	.135	11/32	71
20d	4	.1483	3/8	52
30d	4-1/2	.1483	3/8	46
40d	5	.162	13/32	35

TABLE 11-9
NAIL SIZE AND SPACING FOR ASSEMBLY OF NAILED OPEN CRATES[4]

Fasten		Size and type of nail	Maximum Spacing, in.	Notes
Part	To Part			
Corner strut of end--(1-in. member)	Corner strut of the side	12d	12	
Corner strut of end--(2-in. member)	Corner strut of the side	20d	12	Predrill through sheathing of end and corner strut of end
Sheathing of side	Corner of the end	8d	6 to 8	Stagger
Edge frame member of top--(through sheathing)	Upper frame member of sides	12d	6, center 60 center	
Edge frame member of top	Upper frame member of sides	8d	6 to 8	Space nails between top sheathing
End strut of top	Upper frame member of end	12d	6	Stagger

TABLE 11-10
NAIL SELECTION TABLE FOR NAILING SHEATHING TO CRATE BASE ACCORDING TO GROSS WEIGHT[4]

Nail		Wood group of skids		
Type	Penny size	II	III	IV
Common.	7	20	21	16
. . . Do.	8 or 9	16	17	13
. . . Do.	10	13	14	11
Sinker or cooler.	7	23	26	19
Sinker or cooler.	8 or 9	19	21	16
Sinker or cooler.	10	18	19	14
Corker.	8 or 9	17	19	14
. . . Do.	10	15	16	12

NOTE: There shall be not less than two nails per board, and nails shall not be more than 3 in. apart, nor less than 1-1/2 in. apart.

If the moisture content of lumber is greater than 18 percent, the number of nails required shall be increased one-third.

Nails per each 1,000 - Lb gross load.

TABLE 11-11
SPACING OF NAILS FOR ASSEMBLY OF SIDES, TOP AND BOTTOM TO ENDS OR CLEATS (WOODEN BOXES)[8]

Size of nails	Spacing when driven into side grain (in.)	Spacing when driven into end grain [1] (in.)
Sixpenny or smaller	2	1-3/4
Sevenpenny	2-1/4	2
Eightpenny	2-1/2	2-1/4
Ninepenny	2-3/4	2-1/2
Tenpenny	3	2-3/4
Twelvepenny	3-1/2	3
Sixteenpenny	4	3-1/2
Twentypenny	4-1/2	4

[1]NOTE: When nails are alternately driven into end grain of end and side grain of cleat (such as nailing sides to ends in styles 2, 2-1/2, 3, 4, 4-1/2 and 7) use spacing schedule based on driving nails into end grain.

TABLE 11-12
NAIL SPACING FOR CLEATED PANEL BOXES

Type of container	Type of Shipment	Cleat thickness (in.)	Weight of Box contents (lb.)	Nail Spacing (in.)
Plywood Overlaid Veneer	All load types	All thicknesses		4
Fibreboard	Domestic all load types	9/16	0-75	6
		5/8		6
		11/16		6
		5/8	76-150	5
		11/16		5
		3/4		5
		11/16	151-300	4
		3/4		4
		13/16		3
		7/8	301-400	3
	Overseas all load types	3/4	0-200	4
Plywood (domestic)	All load types	9/16 or 5/8		5
		11/16 or 3/4		4
		13/16 or 7/8		3
(overseas)	Load types 1 and 2	5/8 or 3/4		5
		13/16		4-1/2
		7/8		4
	Load Type 3	5/8 or 3/4		4
		13/16		3-1/2
		7/8		3

TABLE 11-13
SIZE AND SPACING OF NAILS FOR ASSEMBLY OF THE TOP AND BOTTOM MEMBERS TO THE SIDES (WOODEN BOXES)[8]

Thickness of side (in.)	Group I	Group II	Groups III and IV wood	Spacing (in.)	
				Minimum	Maximum
Under 3/4-----------	No nailing permitted				
3/4 thru 7/8, incl. ----	7d	6d	5d	6	8
15/16 thru 1-1/16, incl. -	8d	7d	6d	6	8
Over 1-1/16----------	10d	9d	8d	8	10

TABLE 11-14
ASSEMBLY NAILING OF LUMBER SHEATHED NAILED CRATES[5]

Fasten		Nail size and spacing		Notes
Part	To part	Lumber sheathing	Plywood sheathing	
Sheathing of side and end	Skid and end header (skid base)	Eightpenny minimum size 3-in. maximum spacing	Sevenpenny minimum size 3-in. maximum spacing	See nailing table 11-15 for number required
	End and side sills (sill base)	2 rows up to 4x4 skids 3 rows for 4x6 skid (on edge) 3 rows for all sill bases	2 rows up to 4x4 skids 3 rows for 4x6 skid (on edge) 3 rows for all sill bases	
Corner strut of end	Corner strut of side	Twentypenny-predrill 12-in. spacing	Twelvepenny 12-in. spacing	Predrill for twenty-penny nails, 75 percent of shank diameter
Sheathing of side	Corner strut of end	Eightpenny minimum size 6 to 8-in. spacing	Sevenpenny minimum size 6 to 8-in. spacing	

TABLE 11-15
NAIL SELECTION TABLE FOR NAILING SHEATHING TO CRATE BASE ACCORDING TO GROSS WEIGHT[5]

Type of nail	Size of nail	Wood group of skid		
		II	III	IV
Sinker or cooler	7d	23	26	19
	8d or 9d	19	21	16
	10d	18	19	14
	12d	15	16	12
Corker	7d	24	26	19
	8d or 9d	17	19	14
	10d	15	16	12
	12d	15	16	12

NOTE: Nails shall not be less than 2 per board (lumber sheathing) and shall neither be more than 3 inches apart nor less than 1-1/2 inches apart.

(Nails per each 1,000-pound gross load)

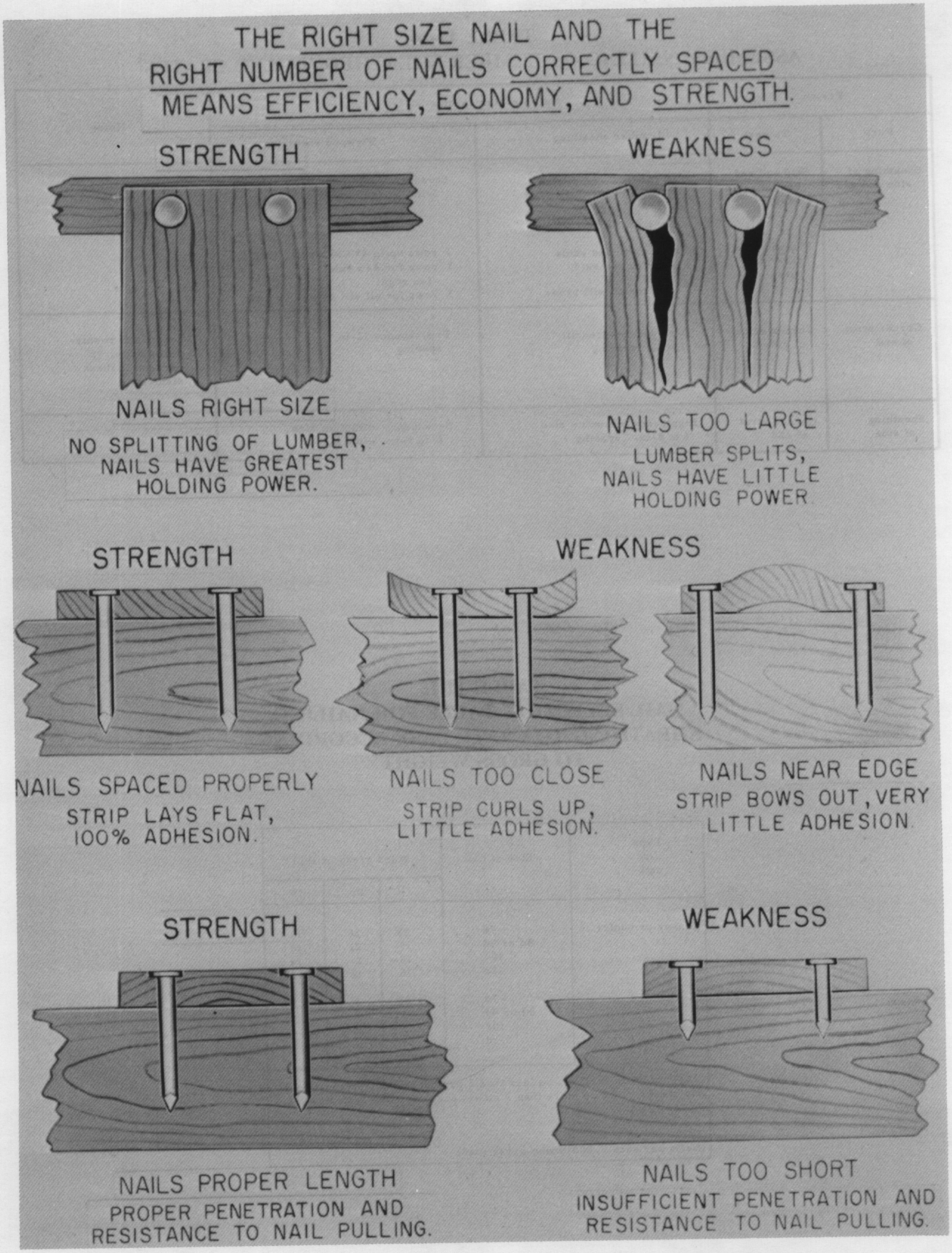


Fig. 11-1. Nailing Practices[6]

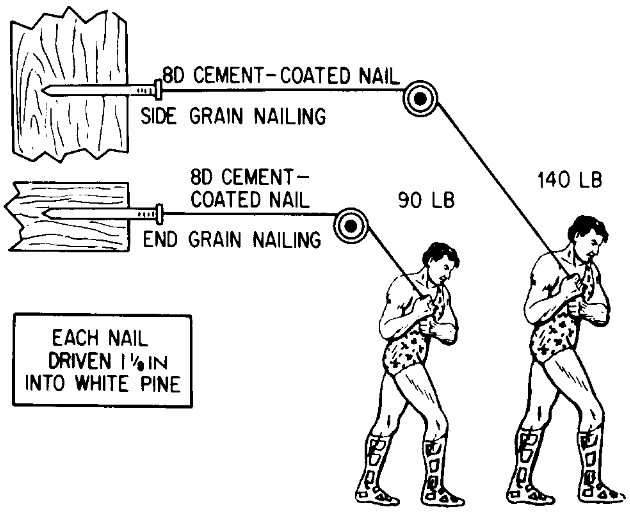


Fig. 11-2. Holding Power of Nails–Side and End Grain Nailing[6]

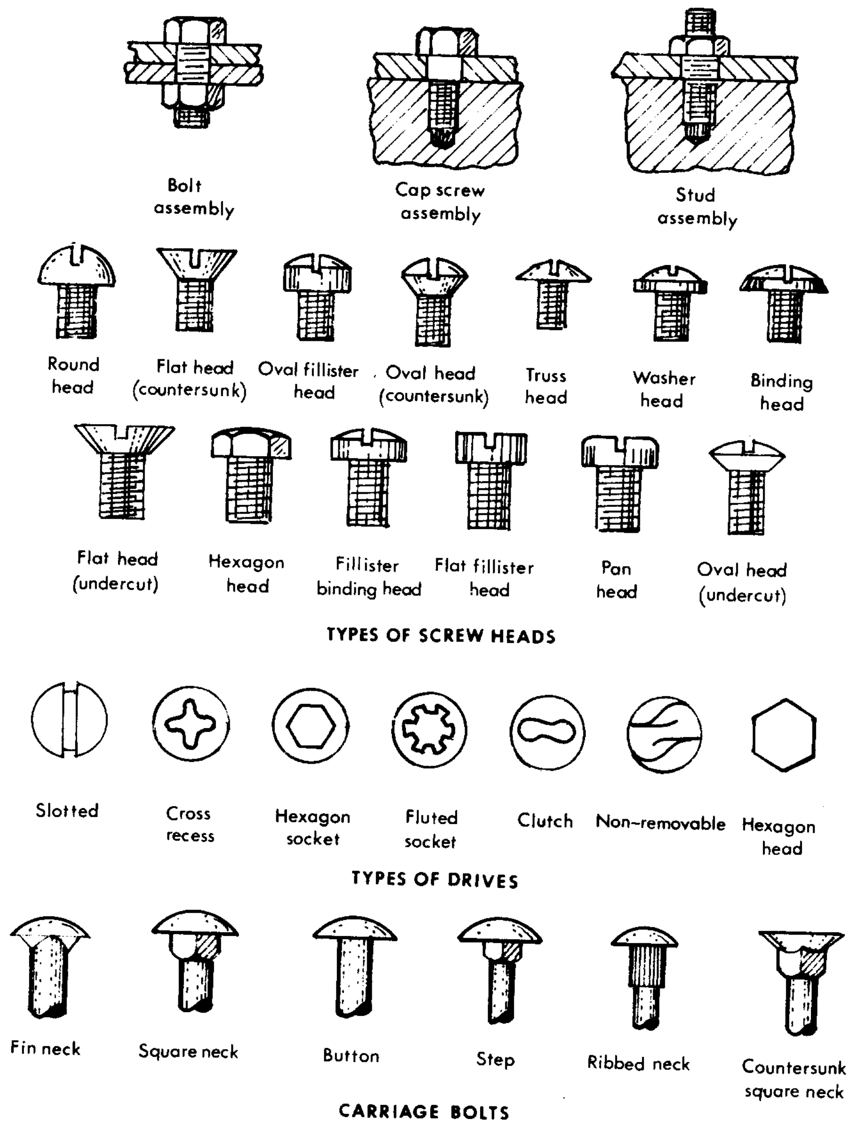


Fig. 11-3. Common Types of Bolt and Screw Heads

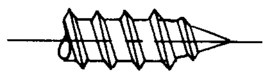
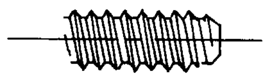
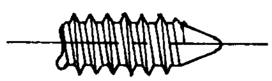
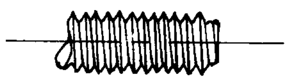
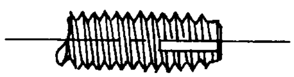
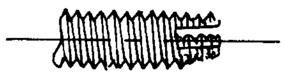
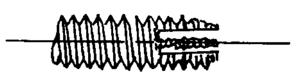
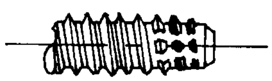
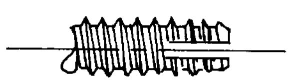
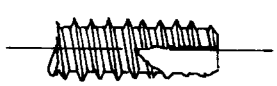
Thread Profiles	SAE and ASA Type	Federal Type		Application
	A	A	Thread Forming Screws	Light gage sheet metal, asbestos comp. impregnated plywood, wood, etc.
	B	B	Thread Forming Screws	Heavy gage sheet metal, non-ferrous castings, plastics, etc.
	BP	BP	Thread Forming Screws	Same as B, but with conepoint to correct for misaligned holes
	C	C	Thread Forming Screws	Standard machine screw thread for thick metals
	D	CS Alternate 1	Thread Cutting Screws	Castings,nonferrous forgings, structural steel, impregnated plywood, etc.
	F	CF	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impregnated plywood, etc.
	F	CF	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impregnated plywood, etc.
	G	CS Alternate 2	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impregnated plywood, etc.
	T	CG	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impregnated plywood, etc.
	BF	BF	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings
	BG	BG	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings
	BT	BG	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings

Fig. 11-4. Common Types of Self Tapping Set and Drive Screws

TABLE 11-16
MATERIALS FOR BOLTS, SCREWS, AND NUTS

Material	Properties	
	Tensile strength (compared to carbon steels)	Corrosion resistance
Carbon steels, SAE 1010 to 1065	---	low
Free-cutting steels, SAE 1111 to 1151	low	low
Stainless steel, type 430 . . .	high	high
Monel metal	high	high
Manganese steels	high	low
Nickel steels	high	high
Molybdenum steels	high	low
Vanadium steels	high	low
Chrome-nickel	high	high
Brass	low	high
Copper	low	high
Silicon bronze	comparable	high
Aluminum	low	susceptible to salt water
Magnesium	low	susceptible to salt water

TABLE 11-17(A)
LAG SCREW SIZE AND QUANTITY SELECTION TABLE FOR BOLTED OPEN CRATES FOR NOMINAL 1-IN. LONGITUDINAL MEMBERS AND 4-IN. SKIDS[4]

	1/2-by 6-in. lag				1/2-by 5½-in. lag				2/3-by 6-in. lag				2/3-by 5½-in. lag			
Net load, lb.	G[1] I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV
8,000	28	24	22	18	32	28	24	22	32	28	26	22	36	32	30	26
7,000	24	22	18	16	28	24	22	18	28	24	22	20	32	28	26	22
6,000	20	18	16	14	24	20	18	16	24	22	18	16	28	24	22	18
5,000	18	16	14	12	20	18	16	14	20	18	16	14	22	20	18	16
4,000	14	12	10	10	16	14	12	10	16	14	12	10	18	16	14	12
3,000	10	10	8	6	12	10	10	8	12	10	10	8	14	12	10	10
	1/2-by 5-in. lag								3/8-by 4½-in. lag							
3,000	18	16	14	12					20	18	16	14				
2,500	14	12	12	10					16	14	12	10				

[1]Refers to the wood group and applies to the skids.
Note. If bolts are used, they shall be the same number and diameter as given for lag screws.

TABLE 11-17(B)
LAG SCREW SIZE AND QUANTITY SELECTION TABLE FOR BOLTED OPEN CRATES FOR NOMINAL 2-IN. LONGITUDINAL MEMBERS AND 4-IN. SKIDS[4]

	3/8-by 7-in. lag				1/2-by 7-in. lag				1/2-by 6½-in. lag				1/2-by 6-in. lag			
Net load, lb.	G[1] I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV
16,000	48	44	36	32	56	48	44	36	64	56	48	44	74	68	60	52
14,000	40	36	32	28	48	44	36	32	56	48	44	36	64	60	52	44
12,000	36	32	28	24	40	36	32	28	48	40	36	32	56	52	44	40
10,000	30	26	24	20	34	30	28	24	40	34	32	26	46	42	38	32
9,000	26	24	22	18	30	28	24	22	36	32	28	24	42	38	34	28
8,000	24	22	18	16	28	24	22	18	32	28	24	22	38	34	30	26
7,000	20	18	16	14	24	22	18	16	28	24	22	18	32	30	26	22
6,000	18	16	14	12	20	18	16	14	24	20	18	16	28	26	22	20
5,000	14	14	12	10	18	16	14	12	20	18	16	14	24	20	18	16
4,000	12	10	10	8	14	12	10	10	16	14	12	10	18	16	14	12
3,000	10	8	8	6	10	10	8	8	12	10	10	8	14	12	12	10

[1] Refers to the wood group and applies to the skids.

Note. If bolts are used, they shall be the same number and diameter as given for lag screws.

TABLE 11-18
FACTORS FOR COMPUTING LATERAL WITHDRAWAL RESISTANCE OF LAG SCREWS FOR VARIOUS HELD MEMBER THICKNESSES[8]

Ratio of thickness of member to shank diameter of lag screw	Factor
2	0.62
2-1/2	0.77
3	0.93
3-1/2	1.00
4	1.07
4-1/2	1.13
5	1.18
5-1/2	1.21
6	1.22
6-1/2	1.22

TABLE 11-19
SHANK HOLE AND PILOT HOLE SIZES FOR WOOD SCREWS[8]

Gage of Screws	Shank clearance holes		Pilot holes for Group IV woods	
Number	Size of twist bit, in.	Gage of drill Number	Size of twist bit, in.	Gage of drill Number
4	7/64	34	1/16	52
5	1/8	31	5/64	49
6	9/64	29	5/64	47
7	9/64	25	3/32	44
8	5/32	20	3/32	40
9	11/64	16	7/64	37
10	3/16	12	7/64	33
11	13/64	7	1/8	31
12	7/32	3	1/8	30

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TABLE 11-20
DETERMINATION OF LEAD HOLE SIZE FOR LAG SCREWS[7]

Diameter of threaded portion of lag bolt, in.	Diameter of lead hole	
	Groups I, II, and III wood, in.	Group IV wood, in.
1/4	3/16	3/16
5/16	1/4	1/4
3/8	1/4	5/16
1/2	3/8	7/16
5/8	3/8	1/2
3/4	1/2	5/8

TABLE 11-21
FACTORS FOR COMPUTING LATERAL WITHDRAWAL RESISTANCE OF LAG SCREWS FOR LOADS PERPENDICULAR TO THE GRAIN[8]

Shank diameter of lag screw in.	Factor
3/16	1.00
1/4	0.97
5/16	0.85
3/8	0.76
7/16	0.70
1/2	0.65
5/8	0.60
3/4	0.55
7/8	0.52
1	0.50

TABLE 11-22
SPACING OF WOOD SCREWS FOR ASSEMBLY OF WOODEN BOXES[8]

Gage of Screws	Spacing when driven into side grain [1], in.	Spacing when driven into end grain [1], in.	Spacing when only top of box is fastened with screws [2], in.
7 or smaller	2	1-3/4	3
8	2-1/4	2	3-1/4
9	2-1/2	2-1/4	3-1/2
10	2-3/4	2-1/2	3-3/4
11	3	3-3/4	4
12	3-1/2	3	4-1/2

[1] NOTE: When screws are alternately driven into end grain of end and side grain of cleat (such as nailing sides to ends in styles 2, 2-1/2, 3, 4, 4-1/2, 5, and 7), use spacing schedule based on driving nails into end grain.

[2] NOTE: Spacing of screws for top and bottom, when driven into sides of boxes, shall be placed 8 to 12 inches apart.

TABLE 11-23
SIZES OF WOOD SCREWS FOR ASSEMBLY OF WOODEN BOXES[8]

Thickness of piece holding point of screw In.	Screw gage for wood groups			
	I	II	III	IV
3/8	6	5	5	4
1/2	7	6	6	5
5/8	8	6	6	6
3/4	9	8	7	7
13/16	10	9	8	8
7/8	10	9	8	8
1	11	10	9	9
1-1/16	12	10	10	9
1-1/8	12	11	10	10
1-1/4	12	12	11	11
1-5/16	12	12	12	12

NOTE: If the required size of screw is unavailable, use next smaller gage and reduce spacing 1/4 in

TABLE 11-24
COMMON FLAT, OVAL, AND ROUND HEAD WOOD SCREW SIZES

Lengths In.	No. 0 diameter 0.060 in.	No. 1 diameter 0.073 in.	No. 2 diameter 0.086 in.	No. 3 diameter 0.099 in.	No. 4 diameter 0.112 in.	No. 5 diameter 0.125 in.	No. 6 diameter 0.138 in.	No. 7 diameter 0.151 in.	No. 8 diameter 0.164 in.
1/4	FR	FR	FR	FR	FR	----	----	----	----
3/8	FR	FR	FR	FRO	FRO	FR	FR	FR	FR
1/2		FR	FR	FR	FRO	FRO	FRO	FRO	FRO
5/8			FR	FR	FRO	FRO	FRO	FRO	FRO
3/4			FR	FR	FRO	FRO	FRO	FRO	FRO
7/8				FR	FR	FR	FR	FRO	FRO
1				FR	FR	FRO	FRO	FRO	FRO
1-1/4					FR	FR	FRO	FRO	FRO
1-1/2					FR	FR	FRO	FRO	FRO
1-3/4							FRO	FRO	FRO
2							FR	FR	FR
2-1/4							FR	FR	FR
2-1/2							FR	FR	FR
2-3/4									FR

Lengths In.	No. 9 diameter 0.177 in.	No. 10 diameter 0.190 in.	No. 11 diameter 0.203 in.	No. 12 diameter 0.216 in.	No. 14 diameter 0.242 in.	No. 16 diameter 0.268 in.	No. 18 diameter 0.294 in.	No. 20 diameter 0.320 in.	No. 24 diameter 0.372 in.
1/2	FR	FR	----	----	----	----	----	----	----
5/8	FR	FR	FR	FR	----	----	----	----	----
3/4	FRO	FRO	FR	FR	----	----	----	----	----
7/8	FRO	FRO	FR	FRO	FR	----	----	----	----
1	FRO	FRO	FRO	FRO	FRO	FR	----	----	----
1-1/4	FRO	FRO	FRO	FRO	FRO	FR	FR	----	----
1-1/2	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	----
1-3/4	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	----
2	FR	FRO	FRO	FRO	FRO	FRO	FRO	FRO	----
2-1/4	FR	FR	FR	FRO	FRO	FR	F	F	----
2-1/2	FR	FR	FR	FRO	FRO	FR	FR	FR	----
2-3/4	FR	FR	F	FR	FR	F	F	F	----
3	FR	FR	F	FR	FR	FR	FR	F	----
3-1/2		FR	F	FR	FR	FR	F	F	F
4				FR	FR	FR	F	F	F
4-1/2				FR	F	F	F	F	F
5				FR	F	F	F	F	F

NOTE: F - flat, O - oval, R- round

TABLE 11-25
BOLT DIAMETER FACTOR[5]

Diameter of Bolt (in.)	Diameter Factor
1/4	2.50
3/8	1.95
1/2	1.68
5/8	1.52
3/4	1.41
7/8	1.33
1	1.27
1-1/4	1.19
1-1/2	1.14
1-3/4	1.10
2	1.07
2-1/3	1.03
3 or over	1.00

TABLE 11-26
WEIGHT OF 100 BOLTS AND NUTS

Length under head (in.)	Bolts with square heads and nuts Diameter of bolt (in.)									Bolts with hexagon heads and nuts Diameter of bolt (in.)				
	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1/2	5/8	3/4	7/8	1
1	4	7	11	15	22	37	56	84	122	19	33	52	76	110
1-1/4	4	7	11	16	23	39	59	88	128	20	34	54	80	116
1-1/2	5	8	12	17	24	41	62	93	133	22	36	57	85	121
1-3/4	5	8	13	18	26	43	64	97	139	23	38	60	89	127
2	5	9	14	19	27	45	67	101	144	24	40	63	93	132
Wt. in lb for each additional inch in length	1.4	2.2	3.1	4.3	5.6	8.7	12.5	17.0	22.3	5.6	8.7	12.5	17.0	22.3

Note: All weights are given in pounds.

TABLE 11-27
SUGGESTED ALLOWABLE LATERAL LOADS FOR BOLTS–IMPACT LOADING

Diameter of bolt (in.)	Allowable load (lb)
3/8	35
1/2	90
5/8	150
3/4	200

TABLE 11-28
FACTORS FOR CALCULATING THE WEIGHT OF LARGE BOLTS

Diameter of Bolt (in.)	1-1/4	1-1/2	1-3/4	2	2-1/2	3
Wt of 1 hex. head and 1 hex. nut	1.7	2.9	4.6	6.8	13.0	22.0
Wt of 1 sq. head and 1 sq. nut	2.0	3.5	5.5	8.1	15.5	26.2
Wt of shank per in. (lb)	0.35	0.5	0.68	0.89	1.4	2.0

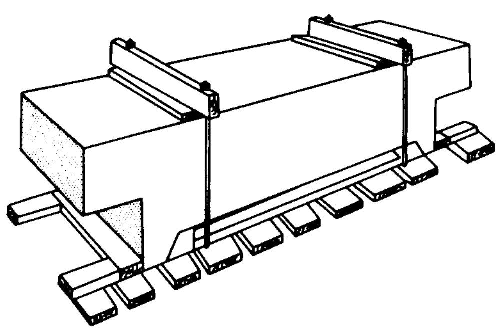
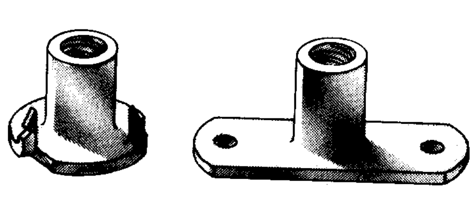


Fig. 11-5. Tie Rods and J-bolts[5]



(Courtesy of United-Carr Fastener Corporation)

Fig. 11-6. "T" Nuts Used in Fabrication of Reusable Panel Boxes

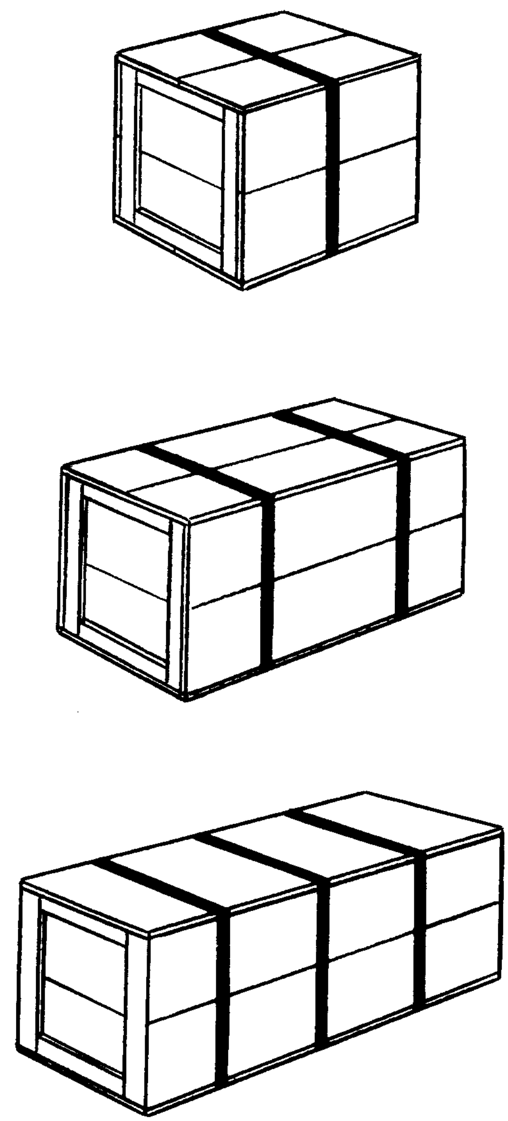


Fig. 11-7. Typical Examples of Wooden Box Strapping

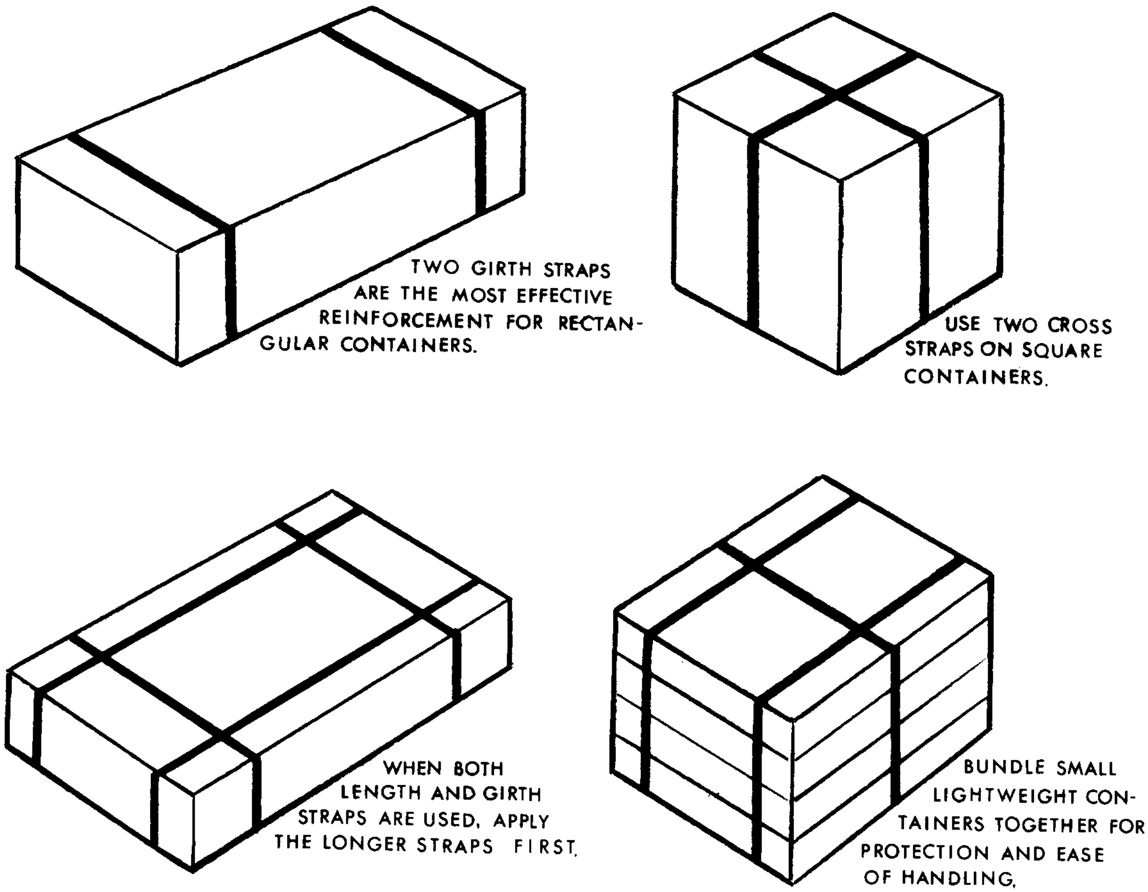


Fig. 11-8. Typical Examples of Fiberboard Box Strapping

TABLE 11-29
NUMBER OF STRAPS AND THEIR DIRECTION TO USE ON CORRUGATED AND SOLID FIBERBOARD BOXES[9]

Direction of bands[1]					
Lengthwise		Girthwise		Horizontal[2]	
Outside width of box, in.	Number of Bands, min[3]	Outside length of box, in.	Number of Bands, min[3]	Outside depth of box, in.	Number of Bands, min[3]
Up to 9	None	Up to 20 in.	1[3]	Up to 18	None
9 to 18	1[3]	20 to 30 in.	2[3]	18 to 30 incl.	1
Over 18 to 30	2[3]	Over 30 to 48	3[3]	Over 30 to 48	2
Over 30 to 48	3	Over 48 to 60	4		
Over 48[4]		Over 60[4]			

[1] Lengthwise. - Encircling top, bottom, and ends. Girthwise. - Encircling top, bottom, and sides. Horizontal. - Encircling sides and ends. See figures for designation of top, bottom, and end faces. Note that the location of the openings determines the designation of the panels, rather than normal storage position.

[2] Horizontal bands are only occasionally required. Where contents exert severe pressure on vertical score lines, bonds should be used.

[3] Full telescope-style boxes, having covers not otherwise sealed to bodies, will usually require use of one or more additional bands, both lengthwise and girthwise when dimensions approach the upper range of the size brackets listed in above table. Additional bands, when required, will be specified by the procuring agency.

[4] As directed by the procuring agency.

TABLE 11-30
METALLIC AND NONMETALLIC STRAPPING REQUIREMENTS

Gross weight of container and contents	QQ-S-781, size of flat steel strapping, class A or B grade 2, standard			PPP-S-760 size of nonmetallic strap		QQ-S-790 size (gage) of round steel strap, finish 2, zinc coated	
lb	Type I	Type III	Type IV	Type II	Type III	Class (A)	Class (B)
Up to 35, incl.	1/4 x 0.015 5/16 x 0.012 3/8 x 0.010	0.138 x 0.025 0.063 x 0.024 1/	1/4 x 0.015	3/8 x 0.015	7/16 x 0.017	16-1/2	16-1/2
Over 35 to 70,incl.	3/8 x 0.015	0.138 x 0.025	3/8 x 0.015	3/8 x 0.015	7/16 x 0.017	16	15
Over 70 to 110, incl.	3/8 x 0.020 1/2 x 0.015		3/8 x 0.020 1/2 x 0.015	1/2 x 0.015 3/8 x 0.020	1/2 x 0.015	14	13
Over 110 to 225 incl.	1/2 x 0.020 5/8 x 0.015		1/2 x 0.020 5/8 x 0.015	1/2 x 0.020	1/2 x 0.020	13	12

1/ 0.063 x 0.024 inch strapping shall be allowed only for V2s sleeve boxes and shall conform to QQ-S-781 except that it shall have a tensile strength of 135 psi, a breaking strength of 205 pounds and a joint strength of not less than 170 pounds.

TABLE 11-31
MINIMUM GAGE OF ROUND WIRE FOR VARIOUS WEIGHTS OF WOODEN BOXES[8]

Net weight of contents (maximum), lb	Gage of wire when different number of wires are used			
	Two Bands		Three Bands	
	100,000 psi tensile strength, in.	140,000 psi tensile strength, in.	100,000 psi tensile strength, in.	140,000 psi tensile strength, in.
70	0.0720(15 gage)	0.0625(16 gage)	0.0720(15 gage)	0.0625(16 gage)
125	.0800(14 gage)	.0720(15 gage)	.0800(14 gage)	.0720(15 gage)
175	.0915(13 gage)	.0800(14 gage)	.0915(13 gage)	.0800(14 gage)
250	.0915(13 gage)	.0915(13 gage)	.0915(13 gage)	.0915(13 gage)
400	.1055(12 gage)	.0990(12-1/2 gage)	.0915(13 gage)	.0915(13 gage)
1,000	---	---	.1055(12 gage)	.0990(12-1/2 gage)

TABLE 11-32
FACTORS FOR CALCULATING ALLOWABLE STRENGTH IN WOOD FASTENERS

Hardwoods	Specfic gravity G and powers (1)				Allowable lateral load constant (K)			Basic stresses for bolts (2)		Species group for connector loads (5)
	G	$G^{3/2}$	G^2	$G^{5/2}$	Nails (3)	Screws (3)	Lag Screws (4)	Parallel to Grain	Perpendicular to grain	
Ash:										
Black	.53	.39	.28	.20	1250	2900	1900	850	300	--
Commercial	.61	.48	.37	.29	1700	4000	2200	1450	500	4
Aspen:										
Big Tooth	.41	.26	.17	.11	900	2100	1700	800	150	1
Quaking	.40	.25	.16	.10	900	2100	1700	800	150	1
Basswood, American	.40	.25	.16	.10	900	2100	1700	----	----	1
Beech, American	.67	.55	.45	.37	1700	4000	2200	1600	500	4
Birch:										
Sweet	.71	.60	.50	.42	1700	4000	2200	1600	500	4
Yellow	.66	.54	.44	.35	1700	4000	2200	1600	500	4
Chestnut, American	.45	.30	.20	.14	900	2100	1700	----	----	2
Cottonwood:										
Black	.37	.22	.14	.08	900	2100	1700	----	----	1
Eastern	.43	.28	.18	.12	900	2100	1700	800	150	1
Elm:										
American	.55	.41	.30	.22	1250	2900	1900	1050	250	3
Rock	.66	.54	.44	.35	1700	4000	2200	1600	500	4
Slippery	.57	.43	.32	.25	1250	2900	1900	1050	250	3
Hackberry	.56	.42	.31	.23	1250	2900	----	----	----	--
Hickory:										
Pecan	.65	.52	.42	.34	1700	4000	2200	2000	600	4
True	.74	.64	.55	.47	1700	4000	2200	2200	600	4
Magnolia, southern	.53	.39	.28	.20	1250	2900	----	----	----	--
Maple:										
Black	.62	.49	.38	.31	1700	4000	2200	1600	500	4
Red	.55	.41	.30	.22	1250	2900	1900	----	----	3
Silver	.51	.36	.26	.19	1250	2900	1900	----	----	3
Sugar	.68	.56	.46	.38	1700	4000	2200	1600	500	4
Oak:										
Commercial Red	.66	.54	.44	.35	1700	4000	2200	1350	500	4
Commercial White	.71	.60	.50	.42	1700	4000	2200	1350	500	4
Sweetgum	.53	.39	.28	.20	1250	2900	1900	1050	300	3
Sycamore, American	.54	.40	.29	.21	1250	2900	1900	----	----	3
Tupelo:										
Black	.55	.41	.30	.22	1250	2900	1900	1050	300	3
Water	.52	.37	.27	.19	1250	2900	1900	1050	300	3
Yellow-Poplar	.43	.28	.18	.12	900	2100	1700	950	220	2

Softwoods	Specfic gravity G and powers (1)				Allowable lateral load constant (K)			Basic stresses for bolts (2)		Species group for connector loads (5)
	G	$G^{3/2}$	G^2	$G^{5/2}$	Nails (3)	Screws (3)	Lag Screws (4)	Parallel to grain	Perpendicular to grain	
Bald Cypress	.48	.33	.23	.16	1125	2700	1700	1450	300	2
Cedar:										
Alaska	.46	.31	.21	.14	1125	2700	1700	1050	250	2
Atlantic White	.35	.21	.12	.07	900	2100	1500	750	180	--
Northern White	.32	.18	.10	.06	900	2100	1500	750	180	--
Port Orford	.44	.29	.19	.13	1125	2700	1700	1200	250	2
Western Red	.34	.20	.12	.07	900	2100	1500	950	200	1
Douglas-fir:										
Coast Type	.51	.36	.26	.19	1375	3300	1900	1450	320	3
Rocky Mountain Type	.45	.30	.20	.14	1125	2700	1700	1050	280	2
Fir:										
Balsam	.41	.26	.17	.11	900	2100	1500	950	150	1
Commercial White	.41	.26	.17	.11	900	2100	1500	950	300	1
Hemlock:										
Eastern	.43	.28	.18	.12	900	2100	1500	950	300	1
Western	.44	.29	.19	.13	1125	2700	1700	1200	300	2
Larch, Western	.59	.45	.35	.27	1375	3300	1900	1450	320	3
Pine:										
Eastern White	.37	.22	.14	.08	900	2100	1500	1000	250	1
Lodge Pole	.43	.28	.18	.12	900	2100	1500	950	220	--
Ponderosa	.42	.27	.18	.11	900	2100	1500	1000	250	1
Red	.51	.36	.26	.19	1125	2700	1700	1050	220	2
Southern Yellow (6)	.59	.45	.35	.27	1375	3300	1900	1450	320	3
Western White	.42	.27	.18	.11	900	2100	1500	1000	250	1
Redwood (old-growth)	.42	.27	.18	.11	1125	2700	1700	1350	250	2
Spruce:										
Engleman	.35	.21	.12	.07	900	2100	1500	800	180	1
Red	.41	.26	.17	.11	900	2100	1500	1050	250	2
Sitka & White	.42	.27	.18	.11	900	2100	1500	1050	250	2

(1) Specific gravity based on weight and volume when oven-dryed.

(2) Basic stresses to be used in determining allowable bolt bearing stresses.

(3) Driven perpendicular to the grain of the wood and loaded either parallel or perpendicular to the grain.

(4) Inserted perpendicular to the grain of the wood and loaded parallel to the grain.

(5) Grouping to be used in determining allowable connector loads. Group 1 woods provide the weakest and Group 4 woods the strongest connector groups.

(6) When graded for density, these species qualify for Group 4 connector loads.

REFERENCES

1. PPP-T-76, *Tape, Pressure-sensitive Adhesive Paper, Water Resistant (for Carton Sealing).*
2. PPP-T-97, *Tape, Pressure-sensitive Adhesive, Filament Reinforced.*
3. UU-T-106, *Tape, Pressure-sensitive Adhesive, Masking, Paper.*
4. MIL-C-3774, *Crates, Wood, Open, 12000 and 16000 Pound Capacity.*
5. MIL-C-104, *Crate, Wood, Lumber and Plywood Sheathed, Nailed and Bolted.*
6. TM 38-230-1, TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I and Vol. II.
7. PPP-C-650, *Crates, Wood, Open and Covered.*
8. PPP-B-621, *Boxes, Wood, Nailed and Lock-corner.*
9. PPP-B-636, *Box, Fiberboard.*

CHAPTER 12

TAPES AND ADHESIVES

Tapes function primarily as closures, but are also used in the bundling, binding, and strengthening of packages. Tapes are also used as a means of sealing against entry of moisture. Adhesives are used exclusively for closure purposes.

This chapter provides data to aid in the use of tapes and adhesives for packaging operations. The different types of tapes and adhesives available are discussed, and their characteristics are given.

12-1 TYPES OF TAPES

The two main types of tapes are:

(1) Pressure-sensitive tapes

(2) Solvent-activated tapes.

Pressure-sensitive tapes may be further categorized as:

(1) Cloth-backed, pressure-sensitive

(2) Paper-backed, pressure-sensitive

(3) Film-backed, pressure-sensitive.

12-1.1 PRESSURE-SENSITIVE TAPES

Pressure-sensitive tapes are those which in dry form are aggressively and permanently tacky at room temperature, and adhere firmly to a variety of dissimilar surfaces upon contact without the need of more than firm finger or hand pressure. They require no activation by water, solvent, or heat in order to exert a strong adhesive holding force toward such materials as paper, cellophane, glass, wood, and metals. Some tapes have a sufficiently cohesive and elastic nature so that despite their agressive tackiness, they can be handled with the fingers and removed from smooth surfaces without leaving a residue.

12-1.1.1 Cloth-backed, Pressure-sensitive Tapes

Cloth-backed tapes have backings of cotton fabric, acetate cloth, or glass cloth. They are usually provided with rubber-based adhesives, and are nondrying, form a good bond to various surfaces when pressed with the fingers. The specifications covering cloth-backed tapes are given in Table 12-1.

12-1.1.2 Paper-backed, Pressure-sensitive Tapes

Paper tapes are furnished with either a creped or a smooth backing. Rope fiber paper is generally used for the smooth-backed paper tapes. Use of this fiber results in a backing that is stronger, stiffer, and more rigid than the crepe-backed paper tapes. However, the creped tapes have greater elongation, and greater conformability over irregular surfaces. Backings of paper tapes are usually treated with a releasing agent to prevent the adhesive from sticking to itself and to make unwinding easier. Paper tapes, in addition to closure and masking, may be used for labeling, marking, and identification.

The properties of various paper-backed tapes are given in Table 12-2. Specifications covering these tapes are given in Table 12-1.

12-1.1.3 Film-backed, Pressure-sensitive Tapes

Film tapes are used for the closure of cartons, for identification, and for reinforcing and strapping of bundles. Tapes of this type are furnished with backings of cellulose acetate, polyethylene, or other polyesters. Film tapes are versatile, and there is great flexibility in developing tapes with specific desirable characteristics, such as conformability over irregular surfaces, adhesion to and removability from metallic surfaces at low temperature, and adhesion to painted surfaces. Specifications covering film-backed tapes are given in Table 12-1.

12-1.2 SOLVENT-ACTIVATED TAPES

Solvent-activated tapes are nonpressure-sensitive and require water or solvent activation. The most common type of solvent-activated tape is gummed, water-

TABLE 12-1
CHARACTERISTICS OF TAPES

Tape Specification	Application	General Charasteristics
	Pressure Sensitive	
Cloth Tapes PPP-T-60, Type IV, Class 1	Intended for sealing containers. For applications less critical than PPP-T-60, Type III tapes	Woven cotton backing
Paper Tapes PPP-T-76	Closure of fiberboard containers	Water resistant; opaque
UU-T-106, Type I	Masking; bridging openings on equipment sprayed with strippable coating compound; not for carton sealing or closure	Creped; not affected by paint, dope, varnish, or other finishing materials; tears easily
UU-T-106, Type II	Same as Type I	Same as UU-T-106, Type I, except that is is not creped
PPP-T-42	Light duty bundling, holding and packaging; temporary closing of chipboard and fiberboard boxes; not intended as a substitute for PPP-T-76	Creped
Film Tapes	High strength characteristics; Maximum resistance to elements; Waterproofing; 2nd vaporproofing; Exterior use	Polyester backing; waterproof and vaporproof; color as specified
PPP-T-60, Type III, Class 2	Attaching and protecting labels; sealing containers	Same as PPP-T-60, Type III, Class 1, except transparent
PPP-T-97, Type I	Reinforcing fiberboard or fiberboard-surfaced containers; strapping; bundling; other miscellaneous uses; interior use	Acetate fiber and/or polyester; transparent; element reinforced with longitudinal glass fibers; nonweatherproof; high elongation; low tensile strength
PPP-T-97, Type II	Same as PPP-T-97, Type I	Same as PPP-T-97, Type I, except lower elongation and medium tensile strength; may be opaque or transparent

TABLE 12-1
CHARACTERISTICS OF TAPES (Cont.)

Tape Specification	Application	General Characteristics
Pressure Sensitive		
PPP-T-97, Type III	Same as PPP-T-97, Type I	Same as PPP-T-97, Type I, except lower elongation and high tensile strength
PPP-T-97, Type IV	Same as PPP-T-97, Type I, except that it is for exterior use	Opaque; element reinforced with longitudinal glass fibers; weatherproof; low elongation; high tensile strength
L-T-99, Type I	Semipermanent labeling and identification	Acetate fiber, Transparent
L-T-99, Type II	Permanent labeling and identification	Same as L-T-99, Type I
MIL-T-22085 Type I	Protection of aircraft and missiles during storage, handling, and shipments; exterior sealing and preservation	Oil and weather resistant; no material specified for backing
MIL-T-22085 Type II	Same as Type I but for flat surfaces only	Weather resistant; not oil resistant; no material specified for backing
MIL-T-43036	Sealing fiber containers (MIL-C-2439), cans (MIL-C-3955), and slip cover metal containers	Polyester backing; filament reinforced; waterproof; water-vaporproof; medium tensile strength
MIL-T-43115	For exterior preservation and sealing of missile material; where excellent seal is necessary and where quick, easy and clean removal is required	Suitable for applications at a temperature as low as -18°C (0°F); performs satisfactorily in temperature range of -53 18° to 60°C (-65° to 140°F)

TABLE 12-1
CHARACTERISTICS OF TAPES (Cont.)

Tape Specification	Application	General Characteristics
	Solvent Activated	
Paper Tapes PPP-T-45 Type I	Sealing closures of fiber boxes and other containers; securing wrappers of packages; banding tubes, wire, hose, etc.	Water-activated gum; opaque; element reinforced with glass, rayon, or sisal filaments in the machine and cross directions; asphaltic binder
PPP-T-45, Type II	Same as PPP-T-45, Type I	Same as PPP-T-45, Type I, except nonasphaltic binder
PPP-T-45, Type III	Sealing closures of fiber boxes and other containers, securing wrappers of packages; banding unwrapped bundles of paper and paper products	Water-activated gum; opaque; not reinforced lightweight for light packages
Grade A	Light duty, for lightweight packages	
Grade B	Medium duty, for medium-sized packages	
Grade C	Heavy duty, for heavy, bulky packages	

activated tape. This tape is made of various weights of paper stock coated on one side with a water-soluble adhesive. Gummed, water-activated tapes are used primarily for closing the flaps and seams of cartons. The specification covering gummed, water-activated tapes is given in Table 12-1.

12-2 CONSIDERATIONS IN CHOOSING A TAPE

The primary considerations in choosing a tape for a particular application are:

a. *Surface to which tape is to be adhered.* The tape must adhere to the surface being taped and remain adhered under all anticipated conditions of transportation and storage.

b. *Removability.* If adhered to the surface of an item, the tape must be removable without disturbing the item or impairing its function.

c. *Application Conditions.* Application conditions include temperature and humidity. These factors are important inasmuch as they change the state of the adhesive side of the tape.

d. *Weight and size of the package.* The weight and size of the package determine the strength required of the tape.

e. *Transportation and storage conditions.* The tape must not deteriorate or lose its adhesiveness during transport and storage.

f. *Cost.* The cost of the tape must be kept at a minimum, but the primary consideration is to choose a tape which adequately protects the package and the packaged item.

TABLE 12-2
PROPERTIES OF PAPER-BACKED TAPES

Backing	Thickness (mils)	Tensile Strength (lb/in. width)	Elongation (% at break)	Tear Resistance	Conformability	Adhesion to Steel (oz/in. width)
Crepe 30 lb	7-10	15-20	10-15	Low	Excellent	20-40
Crepe 40 lb	9-11	25-30	8-12	Med.	Excellent	20-30
Crepe 70 lb	20	40-55	30	High	Excellent	20-30
Flatback	6-8	25-30	5-7	High	Good	25-40
Flatback High Strength	9-15	50-60	8	High	Good	25-35

Note:
The values in this table were compiled from many different sources. They are approximate and can vary widely depending on the test used. Refer to Pressure Sensitive Tapes, H. R. Clauser, Editor, Materials and Methods 43: 123-38, March 1956, Page 126.

12-3 TAPE CHARACTERISTICS

Physical characteristics of the various tapes are given in Table 12-1.

12-4 TYPES OF ADHESIVES

There are three principal classes of adhesives:

(1) Thermoplastic adhesives

(2) Thermosetting adhesives

(3) Miscellaneous water-base adhesives.

The specific types of adhesives within each class are given in Table 12-3. The materials commonly bonded by these adhesives are given in Table 12-4.

12-5 CONSIDERATIONS IN CHOOSING AN ADHESIVE

The considerations involved in choosing an adhesive are similar to those for selecting a tape (par. 12-2).

12-6 ADHESIVE CHARACTERISTICS

Physical and chemical characteristics of the various adhesives are given in Tables 12-5 through 12-10. The Military and Federal Specifications covering adhesives are listed in Table 12-11.

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TABLE 12-3
CLASSIFICATION OF ADHESIVES

Thermoplastic Adhesives	Thermosetting Adhesives
Rubber	Resin
Natural rubber	Urea-formaldehyde
GR-S	Melamine
Neoprene	Acid-catalyzed phenolic
Nitrile	Resorcinol and phenol-resorcinol
Butyl	Phenolic resin
Reclaimed rubber	Polyester
Rubber derivatives	Epoxy
	Polyurethane
Resin	Rubber-Resin
Cellulose	Neoprene-resin
Cellulose nitrate	Nitrile-resin
Cellulose acetate	Thiokol
Ethyl cellulose	Modified Phenolic Resin Blends
Vinyl	Vinyl phenolics
Polyvinyl acetate	Vinyl-formal-phenolic
Polyvinyl alcohol	Vinyl butyral-phenolic
Vinyl vinylidene	Nylon-phenolic
Vinyl butyral	Epoxy-phenolic
	Modified acrylate
Miscellaneous	**Miscellaneous Water-base Adhesives**
Shellac	Vegetable
Manila gum	Starch and dextrene
Rosin	Soybean flour and zein
Limed rosin	Animal Base
Cumarone-indene	Glue (hide, bone, fish)
Polyamide resins	Blood albumen
Acrylic	Casein
Oleoresin	Casein-latex
Asphalt	Inorganic
	Sodium silicate
	Magnesium oxychloride
	Litharge-glycerine

TABLE 12-4
MATERIALS COMMONLY BONDED BY ADHESIVES

Adhesive(1)	Material Bonded									
	Metals	Plastics	Rubber	Glass	Wood(2)	Ceramics	Leather	Textiles	Paper	Fibrous Compo-sition
Thermoplastic Adhesives										
Rubber										
Natural rubber	–	–	–	–	–	–	X	X	–	–
GR-S	X	X	X	–	X	–	–	X	X	X
Neoprene	X	X	X	–	X	–	X	X	–	–
Nitrile(3)	X	X	X	X	X	X	X	X	X	X
Butyl (3)	X	–	X	–	X	–	X	X	–	–
Reclaimed rubber(3)	X	–	X	–	X	–	X	X	–	–
Rubber derivatives	X	–	X	–	–	–	–	–	–	–
Resin										
Cellulose nitrate	X	X	–	X	–	–	X	X	–	–
Cellulose acetate	–	X	–	–	–	–	–	–	X	–
Ethyl cellulose	–	–	–	–	–	–	–	X	X	–
Polyvinyl acetate	X	X	–	X	X	–	X	X	X	–
Polyvinyl alcohol	–	–	–	–	–	–	–	X	X	–
Vinyl vinylidene	–	–	–	–	–	–	–	X	–	–
Vinyl butyral	–	–	–	X	–	–	–	–	–	–
Shellac	X	–	–	–	X	–	–	X	–	–
Manila gum	–	–	–	–	X	–	–	–	–	–
Rosin	–	–	–	–	–	–	–	–	X	–
Limed rosin	–	–	–	–	X	–	–	–	–	X
Cumarone-indene	–	–	–	–	X	–	–	X	–	–
Polyamide resins	–	–	–	–	–	–	–	–	X	–
Acrylic	–	X	–	–	–	–	–	–	–	–
Oleoresin	–	–	–	–	X	–	–	–	X	X
Asphalt	X	–	–	X	X	–	–	X	X	X
Thermosetting Adhesives										
Resin										
Urea-formaldehyde	–	–	–	–	X	–	–	–	–	–
Melamine	–	–	–	–	X	–	–	–	–	–
Acid-catalyzed phenolic	X	–	–	–	X	–	–	–	–	–
Resorcinol and phenol-resorcinol	–	X	–	–	X	–	X	X	X	X
Phenolic resin	X	–	X	X	X	–	–	–	–	–
Polyester	X	X	–	–	–	X	–	–	–	–
Epoxy	X	X	X	X	X	X	–	–	–	–
Polyurethane	X	X	X	X	X	X	–	X	X	X
Rubber-resin										
Neoprene-resin	X	X	–	–	X	–	–	–	–	–
Nitrile-resin	X	–	–	–	–	–	–	–	–	–
Thiokol	X	X	X	X	X	–	–	X	–	–

TABLE 12-4
MATERIALS COMMONLY BONDED BY ADHESIVES (Cont.)

Adhesive[1]	Material Bonded									
	Metals	Plastics	Rubber	Glass	Wood[2]	Ceramics	Leather	Textiles	Paper	Fibrous Compo-sition
Thermosetting Adhesives (Continued)										
Modified Phenolic Resin Blends										
Vinyl formal-phenolic	X	–	X	–	X	–	–	–	–	–
Vinyl butyral-phenolic	X	X	X	–	X	–	–	–	–	–
Epoxy-phenolic	X	X	X	X	X	–	–	–	–	–
Miscellaneous Water-Base Adhesives										
Starch and dextrene	–	–	–	X	–	–	–	–	X	–
Soybean flour and zein	–	–	–	–	X	–	–	–	–	–
Glue (hide, bone, fish)	–	–	–	–	X	–	X	X	X	–
Blood albumen	X	–	–	–	X	–	X	X	X	–
Casein	–	–	–	–	X	–	–	–	–	–
Casein-latex	X	X	–	–	X	–	–	–	–	–
Sodium silicate	–	–	–	–	–	–	–	–	X	–
Magnesium oxychloride	–	–	–	X	–	X	–	–	–	–
Litharge-glycerine	–	–	–	–	–	X	–	–	–	–

(1) This list is not exhaustive nor does it include adhesive tapes and films or sealers. The information is general and not necessarily applicable to all forms of the adhesive or the material.

(2) Includes cork.

(3) Recommended where it is necessary to bond to painted metal surfaces.

TABLE 12-5
CHARACTERISTICS OF THERMOPLASTIC RUBBER ADHESIVES

Adhesive	Strength	Dead-load	Tack	Resistance to Deteriorators					
				Water	Oil	Gaso-line	Heat	Cold	Aging
Rubber Base									
Natural rubber	G	P	E	E	P	P	P	G	F
GR-S	F	P	F	E	P	P	F	G	F
Neoprene	E	G	P to G	E	G	G	G	G	G to E
Nitrile	E	F	P to G	E	E	E	G	G	G
Butyl	F	P	G	E	P	P	P	G	E
Thiokol	F	P	F	E	E	E	F	E	E
Reclaimed rubber	G	P	G	E	P	P	P	G	F
Rubber Derivatives									
Cyclized	G	F	G	E	P	P	F	M	G
Chlorinated	G	F	G	E	G	G	• M	M	G

Note:
E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.

TABLE 12-6
CHARACTERISTICS OF SEVERAL THERMOPLASTIC RESIN ADHESIVES

Adhesive	Commonly Available Form	Resistance to Deteriorators			Special Characteristics	Application
		Water	Grease	Oils		
Shellac	Solvent solution (alcohol), mastic (hot melt)	Good	Good	Good	Resists hydrocarbon solvents; Softened by heat; Useful as primer over metals; Difficult to wet prior to applying other adhesives; As tough as manila gum.	Porous materials; Some metals.
Manila gum	Solvent solution (alcohol), with fillers, mastic	Good	Good	Good	Tougher than hard synthetic resins that are alcohol soluble; Releases solvent quickly; Develops strength rapidly.	
Rosin	Solvent solution, mastic (hot melt)	Poor	Poor	Poor	May be plasticized; Poor aging properties; Subject to oxidation.	Temporary holding uses.
Limed rosin	Mastic	Good	Good	Good	Heat resistance is good (better than that of rosin cements); Fair aging properties; Becomes brittle; Saponified by alkali; Develops strength rapidly.	
Cumarone-indene	Solvent solution (Toluol or Xylol), mastic	Good	Poor	Poor	Low bond strengths; Films are hard, tough; Softens at elevated temperatures; Resists alkali	Wood, felt and cloth (compatible with waxes).
Polyamide resins	Solvent solution, mastic (hot melt)	Poor[1]	Good	Good	Flexible, tough mastics; Nonblocking at room temperatures; Heat seal at about 150 °F.	Glass and paper (Not used alone extensively, usually in combination with other resins).

(1) Improves when combined with shellac.

TABLE 12-7
CHARACTERISTICS OF SEVERAL THERMOSETTING RESIN ADHESIVES

Type	Form	Additive	Pot Life	Setting Temperature, °F (2)	Curing Temperature, °F (3)	Resistance to Deteriorators (1)						Application
						Water	Solvents	Fungus	Weather	Heat	Cold	
Urea-formaldehyde	Powder Liquid	Water Hardener	1 to 24 hr	70 to 210	70 to 210	F to G	E	E	M	P to M	G to E	Wood (interior).
Melamine	Powder	Water	24 to 48 hr	240 to 280	240 to 280	E	E	E	G	E	G	Wood (exterior).
Acid-catalyzed phenolic	Liquid	Hardener	1 to 6 hr	70 to 210	70 to 250	E	E	E	E	E	E	Wood (exterior); Metal to wood.
Resorcinol and phenol-resorcinol	Liquid	Hardener	1 to 6 hr	70 to 210	70 to 210	E	E	E	E	E	E	Wood (exterior); Plastics; Leather; Textiles; Fiberboard; Wood to metal.
Phenolic resin	Liquid Film Powder	— — Water	Indefinite — Indefinite	250 to 300	250 to 300	E	E	E	E	E	E	Wood (exterior); Metals; Glass.
Polyester	Liquid	Hardener	5 minutes to 24 hr	70 to 220	70 to 220	G	E	E	G	G	G	Polyester laminates; Some metals; Ceramics.
Epoxy	Liquid	Hardener	1/2 hr to 6 months	70 to 250	70 to 500	F to G	E	E	G	F	G	Metals; Glass; Wood; Ceramics; Plastics; Some rubbers.
	Powder	—	Indefinite	250 to 500	250 to 500	F to G	E	E	G	G	G	
	Paste	—	1/2 hr to 4 months	250 to 500	250 to 500	F to G	E	E	G	G	G	
Polyurethane	Liquid Liquid	Solvents —	Up to 48 hr	70 to 355	70 to 355	F to G	G	E	G	G	E	Rubber; Metal; Most plastics; Wood; Paper; Cork; Ceramics; Textiles; Glass.

(1) E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.

(2) Lower if acidic setting agents are added.

(3) Cures at the higher temperatures with acid hardeners added.

TABLE 12-8
CHARACTERISTICS OF SEVERAL THERMOSETTING MODIFIED PHENOLIC-RESIN AND RUBBER-RESIN ADHESIVES

Adhesive	Form	Drying Required	Curing Temperature, °F	Resistance to Deteriorators[1]				
				Water	Oil	Gasoline	Heat	Cold
Neoprene-phenolic (resin)	Liquid Film	Yes No	325 to 500	E	E	E	G	E
Nitrile-phenolic (resin)	Liquid Film	Yes No	325 to 500	E	E	E	E	P to G
Vinyl-phenolic	Liquid Film	Yes No	240 to 500	E	E	E	G	G
Nylon-phenolic (polyamide-phenolic)	Liquid	Yes	325 to 500	G	E	E	F to M	G
Epoxy-phenolic (epoxy modified phenolic)	Liquid Film	Yes No	200 to 330	G to E	G	G	E	G

(1) E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.

TABLE 12-9
CHARACTERISTICS OF SEVERAL VEGETABLE BASE AND ANIMAL BASE ADHESIVES

Adhesive	Form	Preparation	Pot Life	Setting Characteristics	Resistance to Deteriorators: Water	Weather	Fungus	Heat	Special Characteristics
Vegetable starch (1)	Powder	Water added	Many days to indefinite if protected from fungus and water.	Sets at room temperature or is cold-pressed; Sets quickly; Develops tack rapidly as water evaporates.	Poor	Poor	Poor	Poor	Applied by hand or machine; Low strength; Light color, Nonstaining; Low cost.
	Water Solution	Generally mixed hot							
Soybean and vegetable proteins	Powder	Add water, mix cold	Several hours.	Sets as water evaporates; Cold press or use heat at 180° to 250 °F.	Fair to Good	Poor	Poor	Poor	Low cost.
Animal-base glue (hide glue) (1)	Powder	Add water	Indefinite if protected from water, fungus, and heat.	Sets at room or high temperatures; Bonds form before glue cools and gels; Sets quickly; Good tack.	Poor	Poor	Poor	Poor	Excellent solvent resistance; Applied by hand or machine; Great strength with wood; Excellent gap-filling properties.
	Flake	Add water							
Blood albumen	Powder	Add water	Several hours to 1 day.	Sets quickly at 180 °F by loss of water and coagulation.	Fair	Poor to Fair	Poor	Fair	Light-colored; Odorless, tasteless, nontoxic; Inexpensive; Moderate durability.
Casein (1)	Powder	Add water	1 to 24 hours.	Sets at room temperature as alkali reacts and water evaporates; Can be hot-pressed.	Fair to Moderate	Poor	Poor	Fair	Good Solvent resistance; Good durability; Fair gap-filling properties.

(1) Resistance can be improved by compounding with other materials.

TABLE 12-10
CHARACTERISTICS OF SEVERAL VINYL ADHESIVES

Type	Form	Resistance to Deteriorators					Special Characteristics	Application
		Water	Gasoline	Grease	Oils	Fungus		
Polyvinyl acetate	Solvent solution	Moderate	Excellent	Excellent	Excellent	Good	Films are water-white, transparent, light stable; Poor weather and heat resistance; Indefinite pot life; Sets at room temperature.	Metals, wood, glass, plastics, leather, cloth.
	Emulsion	Fair(1)	Good	Good	Good	Good	Tasteless, odorless; Poor weather and heat resistance; Indefinite pot life; Sets at room temperature.	Wood, paper.
Polyvinyl alcohol	Water solution	Fair(2)	Excellent	Excellent	Excellent	Can be induced by treatment	Tasteless, odorless.	Wood, paper.
Vinyl-vinylidene	Solvent solution	Excellent	Excellent	Excellent	Excellent	Moderate	Colorless, transparent.	Textiles.

(1) Adequate for most interior uses.

(2) Adequate to prevent delamination of paper.

TABLE 12-11
NUMERICAL LIST OF ADHESIVE SPECIFICATIONS

SPECIFICATION NUMBER	TITLE
MIL-A-388	*Adhesive and Sealing Compounds Cellulose Nitrate Base*
MIL-G-413	*Glue, Marine and Aviation-marine (Waterproof)*
MIL-C-2861	*Cement, Insulation, High Temperature*
MIL-A-3316	*Adhesives, Fire Resistant, Thermal Insulation*
MIL-A-5092	*Adhesive, Rubber Base, General Purpose*
MIL-A-5433	*Adhesive, Application of, Room-temperature and Intermediate-temperature-setting Resin Phenol Resorcinol, and Melamine Base*
MIL-A-5540	*Adhesive, Polychloroprene*
MIL-A-8576	*Adhesive, Acrylic Base, for Acrylic Plastic*
MIL-A-8623	*Adhesive Epoxy Resin, Metal to Metal Structural Bonding*
MIL-A-9067	*Adhesive Bonding, Process and Inspection Requirements for*
MIL-A-13374	*Adhesive, Dextrin, Spiral Tube Winding for Ammunition Containers*
MIL-A-14042	*Adhesive Epoxy*
MIL-A-17682	*Adhesive Starch*
MIL-A-18065	*Adhesives, High Initial Bond*
MIL-A-22010	*Adhesive, Solvent Type, Polyvinylchloride*
MIL-A-22397	*Adhesive, Phenol and Resorcinol Resin Base for Marine Service Use*
MIL-A-22434	*Adhesive, Polyester, Thixotropic*
MIL-A-22611	*Adhesives, for Polyvinylchloride-coated Cloth*
MIL-A-22895	*Adhesive, Metal Identification Plate*
MIL-C-23092	*Cement, Natural Rubber*

TABLE 12-11
NUMERICAL LIST OF ADHESIVE SPECIFICATIONS (Cont.)

SPECIFICATION NUMBER	TITLE
MIL-A-24084	*Adhesive, Plastic Sheet Vibration Damping*
MIL-A-24179	*Adhesive, Flexible Unicellular-plastic Thermal Insulation*
MIL-A-25457	*Adhesive, Air-drying, Silicone Rubber*
MIL-A-25463	*Adhesive, Metallic Structural Sandwich Construction*
MIL-A-43346	*Adhesive, for Field Repair of Tents, Vinyl Coated Fabrics*
MIL-A-45059	*Adhesive for Bonding Chipboard to Terneplate, Tinplate and Zincplate*
MIL-A-46050	*Adhesive, Special, Rapid Room-temperature Curing, Solventless*
MIL-A-46106	*Adhesive-sealant, Silicone, RTV, General Purpose for Electrical and Mechanical Sealing*
MIL-A-52194	*Adhesive Epoxy for Bonding Glass Reinforced Polyesters*
MIL-A-52264	*Adhesive, Synthetic Rubber, Nitrile-rubber and Vinyl-resin Base*
MIL-A-81236	*Adhesive, Epoxy Resin with Polyamide Curing Agent*
MIL-A-81253	*Adhesive, Modified Epoxy Resin with Polyamine Curing Agent*
MIL-A-81270	*Adhesive, Synthetic Rubber*
MIL-A-82484	*Adhesive and Sealing Components, Cellulose Nitrate Base, Solvent Type for Ordnance Use*
MMM-A-100	*Adhesive, Animal Glue*
QQ-C-100	*Cement, Iron and Steel*
MMM-A-121	*Adhesive, Bonding Vulcanized Synthetic Rubber to Steel*
MMM-A-125	*Adhesive, Casein-type, Water-and Mold Resistant*
MMM-A-130	*Adhesive, Contact*

TABLE 12-11
NUMERICAL LIST OF ADHESIVE SPECIFICATIONS (Cont.)

SPECIFICATION NUMBER	TITLE
MMM-A-132	*Adhesive, Heat Resistant, Airframe Structural, Metal to Metal*
MMM-A-138	*Adhesive, Metal to Wood, Structural*
MMM-A-139	*Adhesive, Natural or Synthetic-natural Rubber*
MMM-A-150	*Adhesive for Acoustical Materials*
SS-C-160	*Cement, Insulation, Thermal*
MMM-A-178	*Adhesive, Paper-label, Water Resistant*
MMM-A-179	*Adhesive, Paper-label, Water Resistant, Water Emulsion Type*
MMM-A-180	*Adhesive, Polyvinyl, Acetate Resin Emulsion Alkali Dispersible*
MMM-A-181	*Adhesive, Room-temperature, and Intermediate-temperature Setting Resin Phenol, Resorcinol, and Melamine Base*
MMM-A-182	*Adhesive, Rubber for Cold-Patching*
MMM-A-185	*Adhesive, Rubber for Paper Bonding*
MMM-A-187	*Adhesive, Synthetic, Epoxy Base Paste Form, General Purpose*
MMM-A-188	*Adhesive, Urea-resin-type Liquid and Powders*
MMM-A-189	*Adhesive, Synthetic-rubber Hot or Cold Bonding*
MMM-A-193	*Adhesive, Vinyl Acetate Resin Emulsion*
MMM-A-250	*Adhesive, Water-resistant, for Sealing Fiberboard Boxes*
MMM-A-260	*Adhesive, Water-resistant, for Sealing Waterproofed Papers*

BIBLIOGRAPHY

PPP-T-42, *Tape, Pressure-sensitive Adhesive (General Packaging Application).*

PPP-T-45, *Tape, Gummed, Paper, Reinforced and Plain, for Sealing and Securing.*

PPP-T-60, *Tape, Pressure-sensitive Adhesive, Waterproof, for Packaging.*

PPP-T-76, *Tape, Pressure-sensitive Adhesive Paper, Water Resistant (for Carton Sealing).*

PPP-T-97, *Tape, Pressure-sensitive Adhesive, Filament Reinforced.*

UU-T-101, *Tape, Gummed, Mending and Reinforcing, Paper and Cloth.*

UU-T-106 *Tape, Pressure-sensitive Adhesive, Masking, Paper.*

L-T-99, *Tape, Pressure-sensitive Adhesive, Identification (Acetate-fiber).*

MIL-T-43115, *Tape, Pressure-sensitive Adhesive, for Preservation and Sealing.*

MIL-A-374, *Adhesive, Paste, for Demolition Charges.*

MIL-A-928, *Adhesive, Metal to Wood, Structural.*

MIL-C-2908, *Cement, Finishing, Insulation.*

MIL-A-3167, *Adhesives (for Plastic Inhibitors).*

MIL-A-3920, *Adhesive, Optical Thermosetting.*

MIL-A-3941, *Adhesive, Paper Label, Water-resistant.*

MIL-A-9117, *Adhesive, Sealing, Aromatic Fuel Cells and General Repair.*

MIL-C-12850, *Cement, Rubber.*

SS-C-153, *Cement, Bituminous, Plastic.*

MIL-HDBK-700(MR), *Plastics.*

CHAPTER 13

MARKING

13-1 GENERAL

Markings applied to labels or directly to barriers or interior containers identify the packaged item and give other important information in regard to the unit or intermediate packages. Lack of proper markings on unit or intermediate packages will cause serious difficulties and problems in the supply system. A unit or intermediate package is not complete until it has been properly identified. Table 13-1 gives instructions on the marking and labeling of unit packages. The requirements for lettering, waterproofing, and securing of labels are discussed in par. 13-4.

13-2 MARKING

Marking of unit and intermediate packages will be done in accordance with MIL-STD-129, *Marking for Shipment and Storage,* which requires the following information to appear on all unit and intermediate packages (see Fig. 13-1 for illustration):

a. Federal Stock Number

b. Item description

c. Quantity and unit

d. Contract or purchase order number

e. Level of preservation and packaging and date.

Basic markings for packs are illustrated in Fig. 13-2 for a box under 10 cu ft.

13-3 REQUIREMENTS

Unless otherwise specified, marking requirements are identical for all levels of packaging and packing. The color of all markings shall be black, except when applied to surfaces on which black is not legible, then the color used shall provide a definite contrast. The hand lettering or writing of markings is not permitted unless specifically authorized except for piece number, total pieces, and weight and cube information.

13-4 LABELS

Paper labels are often used to apply identification and special markings to containers. Required markings on labels for interior packages shall be printed, typed, or reproduced. The size of labels, up to a maximum of 28 sq in. shall be consistent with the size of the package, and the lettering shall be of a size which will permit ready identification. Pressure-sensitive and heat-activated, plastic coated labels may be used in lieu of paper labels on interior packages only when authorized by the cognizant agency (Ref. 1). Labels for level A packages will be secured with water-resistant label adhesive conforming to MIL-A-105, MIL-A-178, or MIL-A-179. Labels for Levels B and C packages will be secured with adhesive in accordance with commercial practice. Definitions of Levels A, B, and C are in par. 1-3-2. All paper labels for Level A packs shall be waterproofed by coating the exterior (outer) surface of the label with a waterproof lacquer, varnish, or acrylic coating compound. When the level of packaging is not known, label securing requirements for Level A will apply.

13-5 SPECIAL MARKING

Special markings will be in accordance with the requirements of MIL-STD-129 and the contract or order. Interior packages containing radioactive material will be marked in accordance with MIL-M-19590.

Two examples of special markings are shown here in Figs. 13-3 and 13-4. The first example shows typical handling and special markings which are required under certain circumstances. The second example is the International Logistic Label which is required for most shipments to foreign governments and international or-

TABLE 13-1
MARKING REQUIREMENTS FOR THE METHODS OF PRESERVATION

Method of Preservation	Marking and Labeling (See note 1)
Method I	Label on initial wrap and on container when used. (Identification not required on grease-proof wraps placed in snug containers where identification is on the container.)
Submethod IA-5	Markings applied directly on metal container.
Submethod IA-6	Markings applied directly on container.
Submethod IA-8	Markings applied on bag and on container when used. See note 2.
Submethod IA-13	Markings applied on container.
Submethod IA-14	Markings applied on outer container.
Submethod IA-15	Markings applied on barrier and on outer wrap when used.
Submethod IA-16	Markings applied on barrier and outer container.
Submethod IB-1	Markings applied to barrier and on overwrap or container when used.
Submethod IB-2	Markings applied to barrier and on overwrap or container when used.
Submethod IC-1	Markings applied on bag and on container when used. See note 2.
Submethod IC-2	Markings applied on barrier and outer container when used.
Submethod IC-3	Markings applied on bag and on container when used. See note 2.
Submethod IC-4	Markings applied on container.
Submethod IC-7	Markings applied on blister package. See note 2.
Submethod IC-8	Markings applied on skin package. See note 2.

TABLE 13-1
MARKING REQUIREMENTS FOR THE METHODS OF PRESERVATION (Cont.)

Method of Preservation	Marking and Labeling (See note 1)
Submethod IIa	Markings applied on barrier and outer container. See note 2.
Submethod IIb	Markings applied on outer container.
Submethod IIc	Markings applied on bag and on container when used . See note 2.
Submethod IId	Markings applied directly on metal container.
Submethod IIe	Markings applied on barrier and outer wrap when used.
Submethod IIf	Markings applied on container.
Method III	Markings on wrap and on container when used. See note 2.

NOTE:
1. Transparent or opaque labels may be inserted in transparent unit containers when the label can be placed in a stationary position and will not affect or be affected by the method of preservation. Opaque labels shall not obscure more than 50 percent of one surface of transparent unit containers.

2. When a container for a unit or multiple unit package is used also as an exterior shipping container, the marking applicable to shipping containers as specified in MIL-STD-129 will be used in lieu of package markings. Identification is not required on wraps placed in snug containers where identification is on the container.

ganizations. In all cases, and because of possible exceptions, MIL-STD-129 must be consulted for full qualification of markings.

13-6 PRECAUTIONARY LABEL (METHOD II)

To prevent premature opening, the date of preservation is included as part of the identification markings (Fig. 13-1). If space for a Method II label (Fig. 13-5) or stamp is not available, the words "METHOD II PACK DO NOT OPEN UNTIL READY FOR USE" in as large letters as possible, will be placed below the last line of the identification markings.

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13-7 MIL-STD-129

The previous paragraphs have briefly covered the marking requirements as specified in accordance with MIL-STD-129. The details are not covered since the standard is already given wide distribution. However, what has been presented in this chapter was done solely to bring about an awareness of the importance of marking and any considerations which may be required in

pack and packaging design. MIL-STD-129 should be consulted for the marking procedures and materials for general supplies, petroleum and steel products, household goods, subsistence items, ammunition, and radioactive materials. This Standard provides the requirements for the uniform marking of military supplies and equipment for shipment and storage. It accommodates the requirements for coded and in the clear data, and the forms required by Military Standard Requisitioning and Issue Procedure (MILSTRIP) and Military Standard Transportation and Movement Procedures (MILSTAMP) for movement processing.

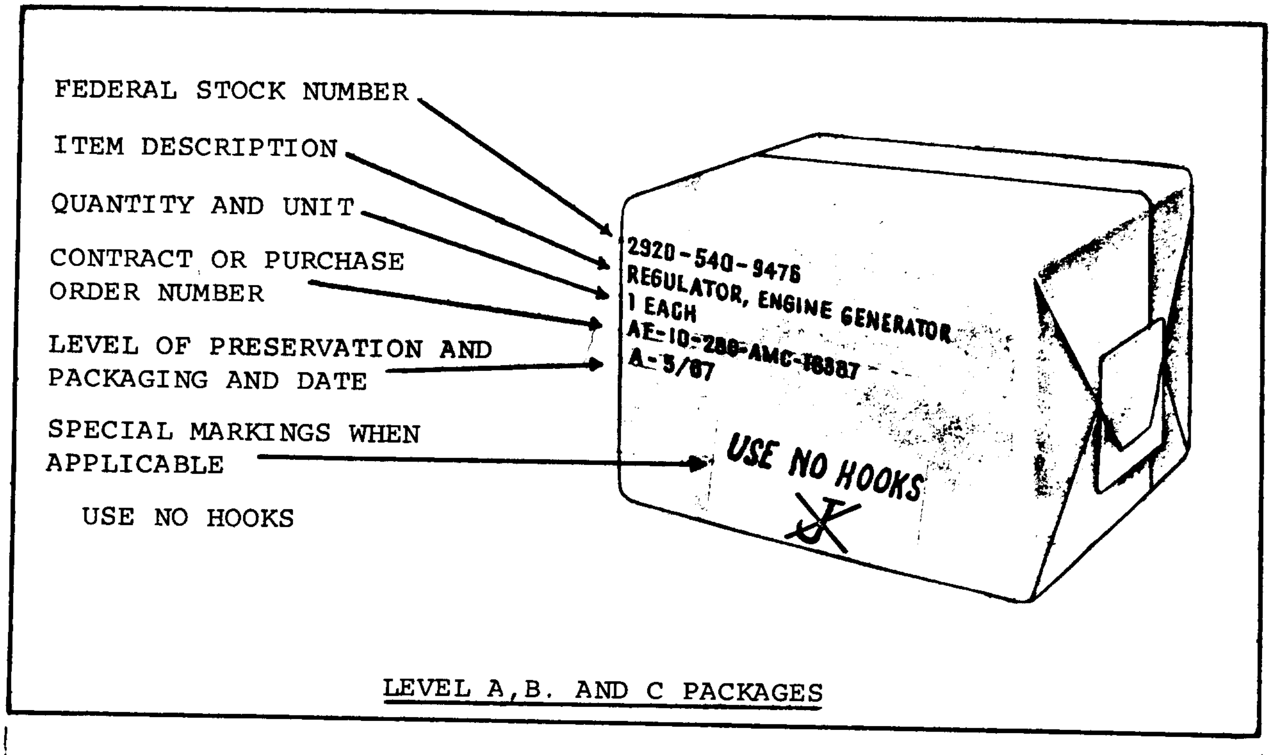
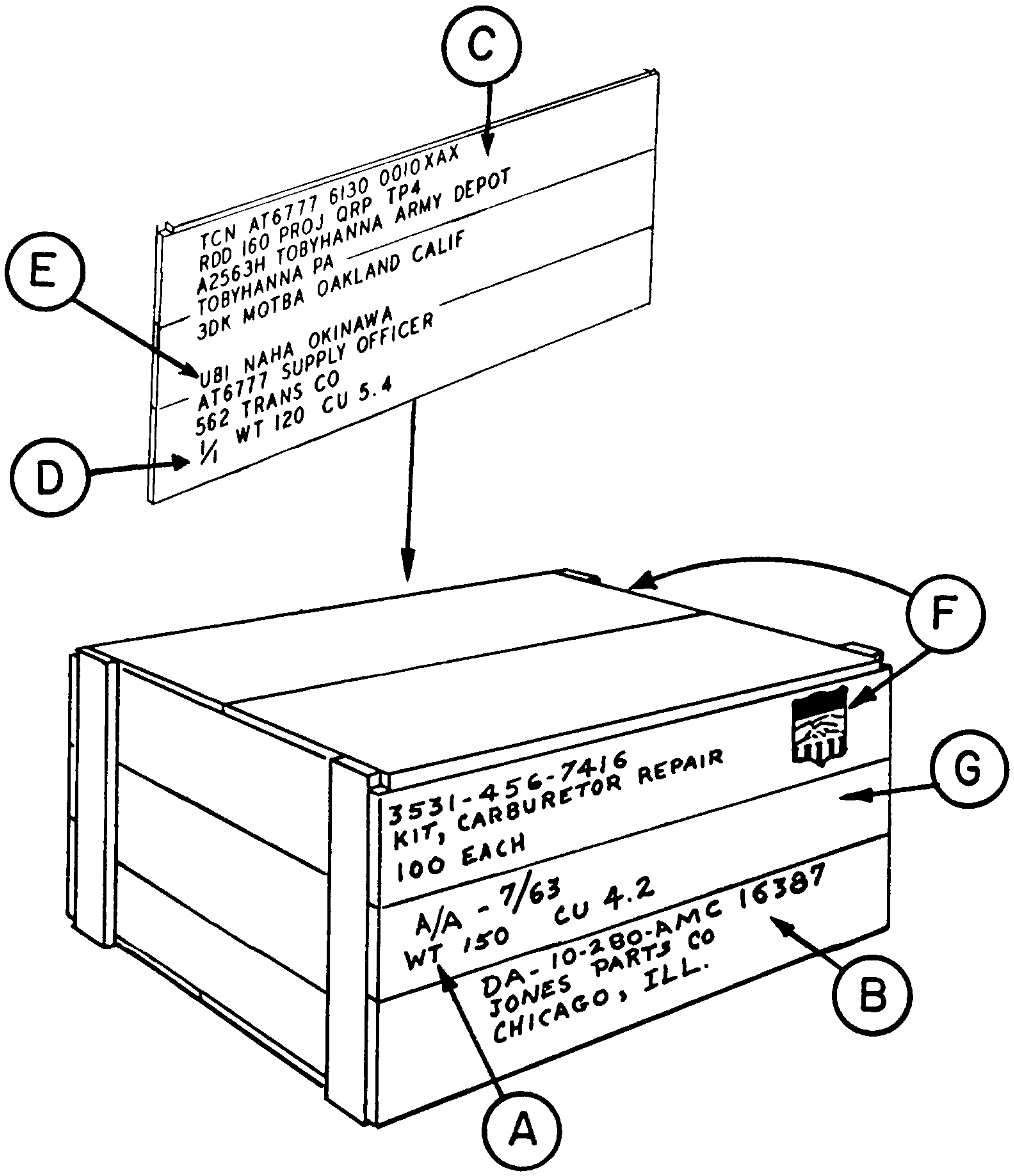


Fig. 13-1. Interior Package Markings (MIL-STD-129)



REQUIRED MARKING

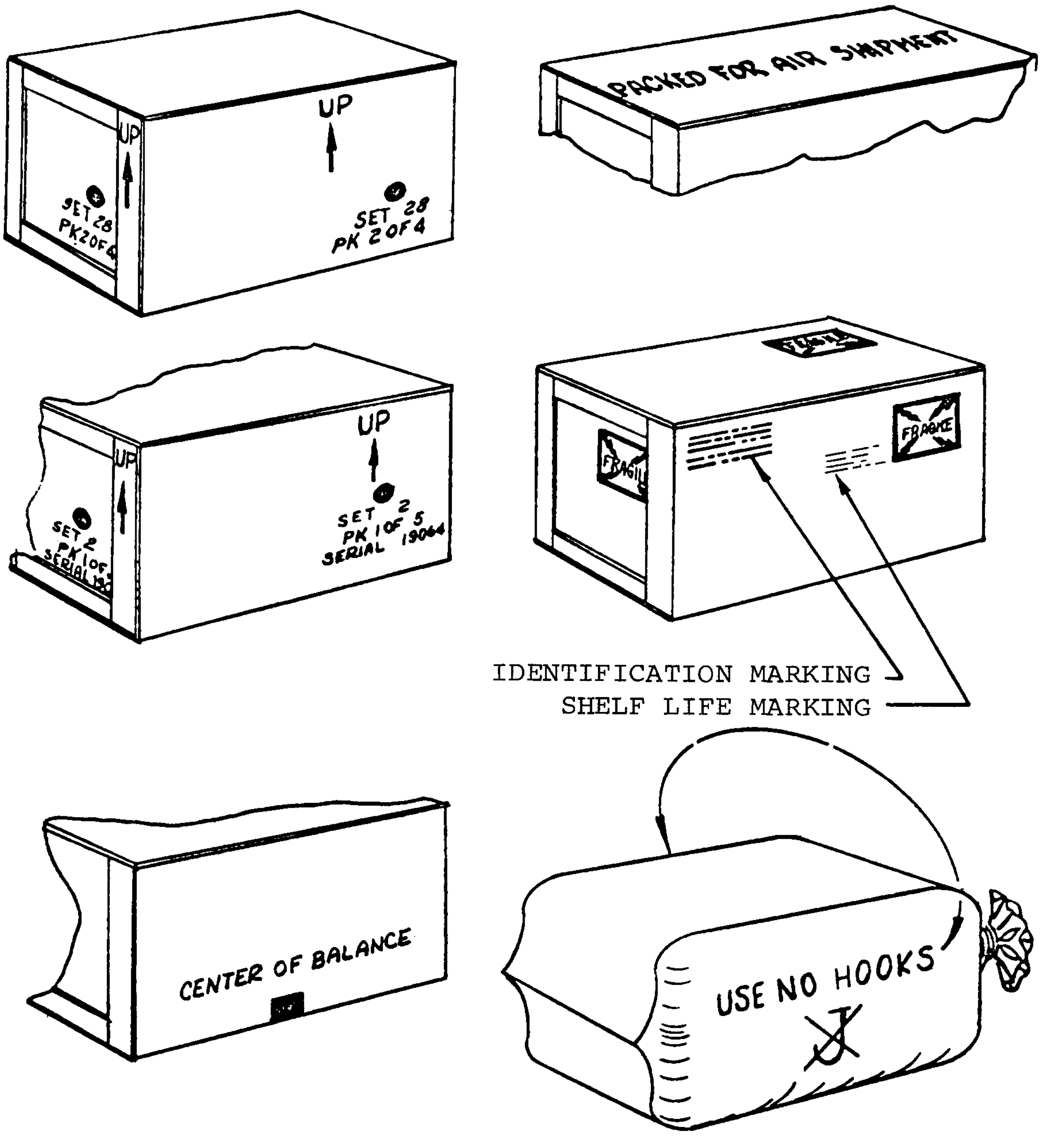
A IDENTIFICATION MARKING
B CONTRACT DATA MARKING
C DOMESTIC ADDRESS
D SHIPPING PIECE NUMBER

ADDITIONAL MARKINGS WHEN REQUIRED

E OVERSEAS ADDRESS
F INTERNATIONAL LOGISTIC LABEL OR STAMP
G SPECIAL MARKINGS

NOTE: LEVEL C SHIPMENTS MAY HAVE MARKINGS APPLIED BY MEANS OF LABELS

Fig. 13-2. Basic Markings for Box Under 10 Cu Ft



TYPE I SHELF LIFE
CURED 2Q 68
EXPIRES 2Q 69

TYPE II SHELF LIFE
MFD 9/68
EXPIRES 10/68
INSPECT/TEST TEST NO.

TYPE II SHELF LIFE
ASSEMBLED 9/67
EXPIRES 10/68
INSPECT/TEST TEST NO.

NOTE: THE EXPIRATION DATE FOR DRUGS AND BIOLOGICALS SHALL BE SHOWN FULL AND IN THE CLEAR, I.E., MAY 10, 1968.

Fig. 13-3. Typical Markings (Handling and Special)

NOTE: Unless otherwise specified in the contract, order, requisition, or by the procuring activity, all International logistic shipments except Foreign Miliary Sales; Supply Support Arrangement shipments; and shipments to Logistical Center Japan, Laos, and Viet Nam shall be identified in accordance with the marking requirements of MIL-STD-129. Foreign Civilian Aid-Administration for International Development (AID) Shipments shall also be excepted unless requested by requisitioner.

Fig. 13-4. International Logistic Label

Fig. 13-5. Method II Label

REFERENCE

1. MIL-STD-129, *Marking for Shipment and Storage.*

BIBLIOGRAPHY

MIL-STD-290C, *Packaging, Packing, and Marking of Petroleum and Related Products.*

MIL-STD-755, *Labels Containing Symbols for Packages and Containers for Hazardous Industrial Chemicals and Materials.*

MIL-STD-163, *Steel Mill Products Preparation for Shipment and Storage.*

MIL-M-19590, *Marking of Commodities and Containers to Indicate Radioactive Material.*

MIL-L-19868, *Labels, Paper, Pressure-sensitive Adhesive for Hazardous Industrial Chemicals and Materials.*

CHAPTER 14

METHODS OF HUMIDITY CONTROL

Earlier chapters of this handbook discuss deterioration, its causes, and various packaging methods used by the military to combat deterioration of items. This chapter describes methods of preserving items through humidity control.

14-1 CONTROL OF HUMIDITY

Items can be protected from the harmful effects of high humidity in one of two ways: (1) by having a barrier "wall" interposed between the surface of the item and the surrounding atmosphere, or (2) by controlling the humidity level of the atmosphere surrounding the surface of the item. The imposing of a barrier between the item and the atmosphere is usually accomplished by enclosure in a hermetically sealed container, enclosure in waterproof- and water-vaporproof-type barrier materials, or treating the item with contact preservatives and surface coatings. When the use of a barrier is impossible or undesirable and the item under consideration requires environmental protection, then the humidity must be controlled.

14-1.1 SATISFACTORY HUMIDITY LEVEL

Extensive testing and evaluation have shown that an atmospheric range of 40 to 50 percent relative humidity is satisfactory for the protection of most military materiel from the effects of corrosion and micro-organism growth. Variations over and under the reference range are permissible when necessary to accomplish the most economical cycling of dynamic dehumidification equipment. These variations are only permissible, however, to the extent necessary to maintain an average humidity of 40 to 50 percent. Controlled humidity facilities should not be operated for any extended period at a relative humidity lower than 30 percent. Many materials such as wood, cotton, and plastic are weakened or deteriorated by excessively low humidities.

14-1.2 TYPES OF CONTROLLED HUMIDITY

There are two basic types of controlled humidity: static dehumidification, and dynamic dehumidification. In determining which type to use in a particular instance, each must be evaluated as to its advantages, disadvantages, and comparative economical value in the specific area of preservation or application involved. Fig. 14-1 presents some of the considerations in selecting the type of dehumidification.

14-1.2.1 Definitions

Various terms of importance in the area of controlled humidity are defined as follows:

a. *Absorption.* The penetration of one substance into the mass of another.

b. *Adsorption.* A concentration of a substance at a surface or interface resulting from the attraction of molecules of the two substances. An example of this is the condensation or adhesion of gases or liquids on the surface of solids.

c. *Desiccant.* A dehydrating agent. A material that takes up moisture from its surroundings by physical or chemical means. Most desiccants used in military packaging are adsorbers.

d. *Relative humidity.* The ratio of the actual water vapor content of air to the maximum amount of water vapor the air can retain without precipitation at a given temperature and pressure. Relative humidity is expressed as a percent of saturation.

e. *Absolute humidity.* Mass of water vapor present in a unit volume of the atmosphere, usually measured as grams per cubic meter. It may also be expressed in terms of the actual pressure of the water vapor present.

f. *Dew point.* The temperature at which air or other gases become saturated with vapor, causing the vapor to deposit as a liquid, i.e., the temperature at which 100 percent relative humidity is reached.

g. *Method II Preservation.* Sealing of items to be protected in a water-vaporproof barrier with a static desiccant charge (with contact preservative when re-

quired). Dynamic dehumidification and mechanically controlled humidity levels are not covered under this method.

14-1.2.2 Static Dehumidification

Static dehumidification for performance of Method II preservation is generally accomplished by placing a chemical agent (usually a desiccant) in the space to be dehumidified. This agent either absorbs or adsorbs water from the surrounding atmosphere. Inasmuch as all such materials have a limit to their ability to take water from the atmosphere and hold it, a means must be provided for preventing a continuous resupply of moisture-laden air or free water from reaching the area being dried by the chemical agent. This function is served by either sealed containers or sealed barrier wraps. For military packaging purposes, an effective barrier must have a water-vapor transmission rate of no more than 0.05 to 0.07 gram per 100 sq in. surface area in 24 hr.

Existing container and barrier materials differ in their water-vapor transmission rates and, consequently also differ in their efficiency in maintaining a desired moisture level in a package over a period of time. The most commonly used barriers for this purpose, in their order of effectiveness, are: rigid and semi-rigid metals, usually steel or aluminum; plastic metal-plastic laminated flexible barriers; semi-rigid combinations of foil-plastic and paper; laminated plastic films; and single-ply plastic films.

In the case of single-ply unsupported plastic film, new materials are now available which are equal to the plastic-foil flexible combinations. These new plastic materials, however, cost approximately four times as much as the plastic-foil combinations and thus are not used as extensively.

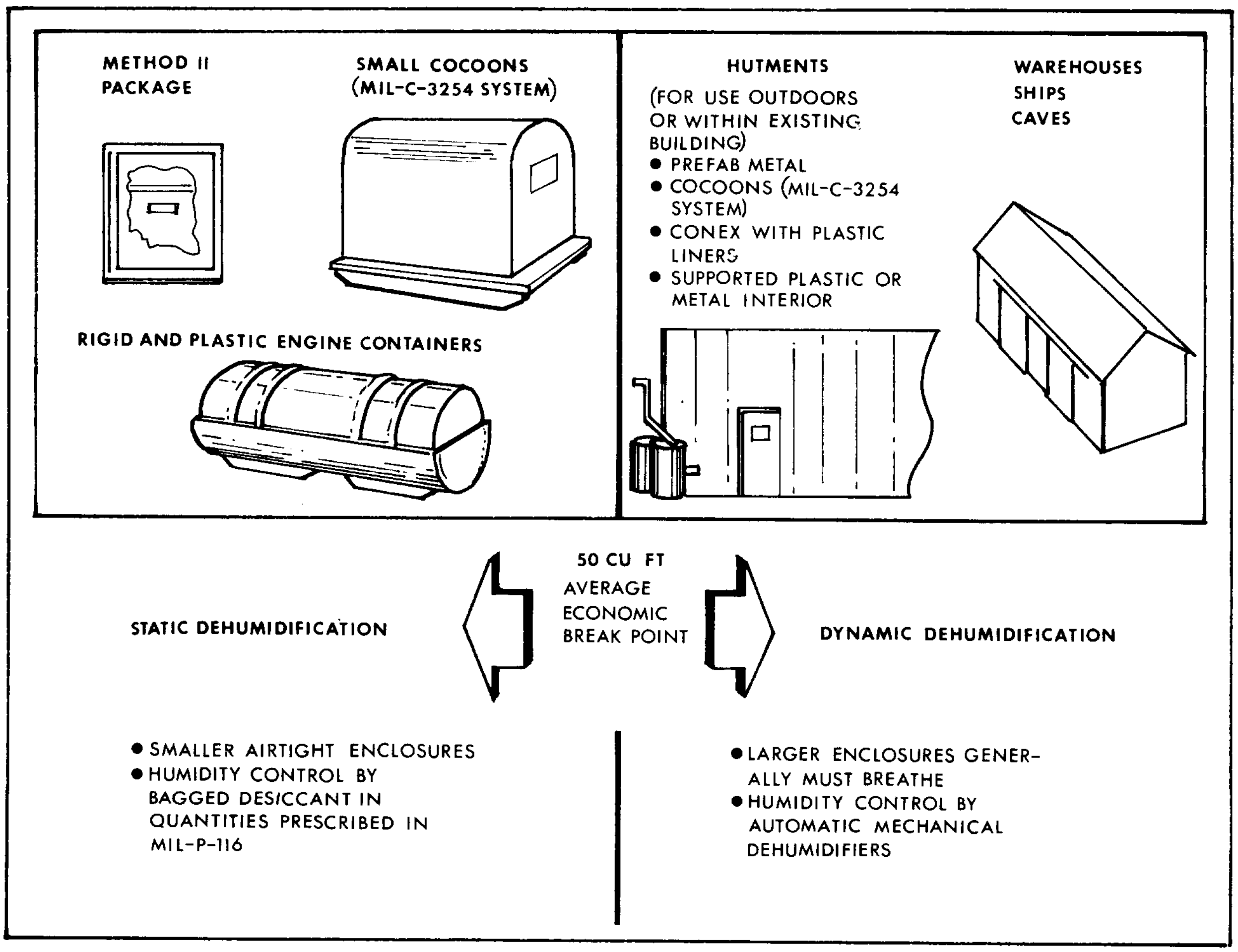


Fig. 14-1. Static vs Dynamic Dehumdification

In the use of flexible barriers, the item to be packaged is enclosed with desiccant in a heat sealed barrier material. The enclosed air volume in barrier packs should be kept to a practical minimum, consistent with good packaging practices. Sufficient cushioning must be provided to prevent the item from puncturing the barrier and destroying its water-vapor protection. Sufficient barrier material must also be provided to permit opening and resealing the pack during use.

Sealed metal containers used as barriers are of three types: pressurized, free-breathing, and valve-controlled breathing. Each type has advantages and disadvantages in weight, effectiveness of protection, and life span. The order of preference in weight is free breather, controlled breather, and pressurized. The order of preference in effectiveness of protection and life span is pressurized, controlled breather, and free breather. From this it is evident that the requirements conflict. The choice of the proper container, then, must be carefully considered with regard to length of storage needed, severity of environment to be encountered, and costs of manufacturing and shipping as related to container weight. The various aspects of these containers are discussed in detail in Chapter 10.

Rigid and semi-rigid containers of materials other than metal are also used in Method II packs. These can include fiber drums, plastic containers, rubber containers, etc. Containers of these types (with the exception of fiber drums) are usually of special design for one specific application. Desiccation is the same as for metal containers.

The amount of desiccant provided in barrier packs is dependent upon the surface area of flexible barrier packs and upon the volume of rigid containers (see par. 14-3 for determination of amount of desiccant required). When dunnage or cushioning is used within the pack, additional desiccant must be provided to compensate for the moisture trapped in the dunnage material. In free-breather or controlled-breather containers, the desiccant must not only dry out the initial container atmosphere, but also the air breathed in during the container storage duration.

14-1.2.3 Dynamic Dehumidification

Dynamic dehumidification involves either the continuous or intermittent processing of the air volume in an enclosure in such a way that the relative humidity is maintained constant at some acceptable level. The three processes by which dynamic dehumdification can be accomplished are:

(1) *Dehumidification Machines.* These machines employ one or more desiccant beds, and the necessary air ducts, filters, fans and heaters. The air is first filtered to remove dirt and dust, then drawn over the desiccant bed where moisture is removed, and finally returned to the space being dehumidified. If only one desiccant bed is used, it must be reactivated periodically, and consequently the machine operated intermittently. If two beds are used (Fig. 14-2), one can be reactivated while the other is in operation, and the machine is thus capable of continuous operation. Internal heaters and outside air are used for the reactivation process.

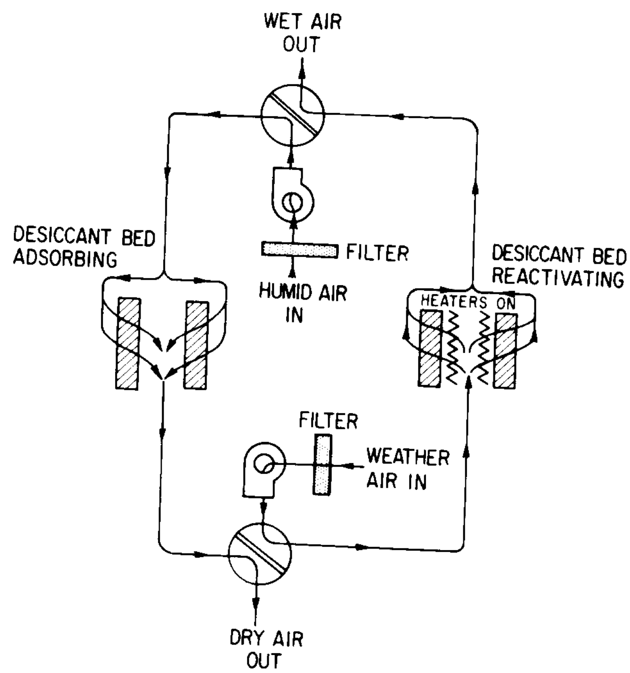


Fig. 14-2. Dehumidification Machine Employing Two Desiccant Beds

Dehumidification machines are relatively simple in design and operation. They are capable of removing moisture efficiently at temperatures from 0° to 150°F, making them ideal for use in unheated buildings.

(2) *Refrigeration.* Dehumidification by refrigeration (Fig. 14-3) involves the passing of the air to be dehumidified over cooling coils. As the air is cooled, its moisture-holding capability drops to the point where condensation takes place and free-water is released. This is the dew point. The water collects on the cold surface in the form of frost. After passing the cooling coils, the air is warmed by being passed over some type of heating element before it is returned to the area being dehumidified. The relationships among temperature,

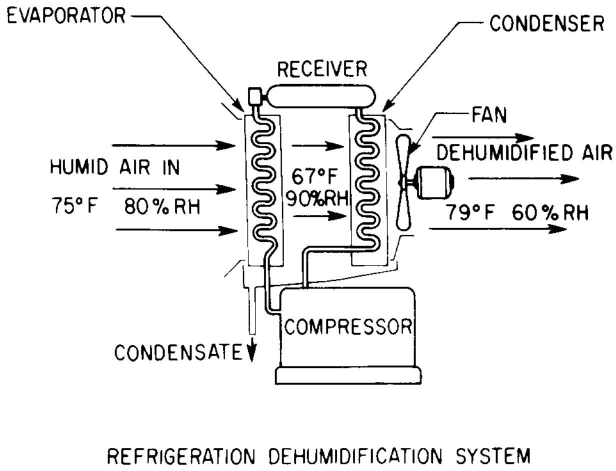


Fig. 14-3. Dehumidification by Refrigeration

relative humidity, and absolute humidity can be determined from Fig. 14-4.

The use of refrigeration for dehumidification is feasible only in those cases where the temperature of the space to be dehumidified does not fall below about 60°F, such as in tropical or semi-tropical climates, or heated warehouses.

(3) *Heating*. The use of heating to accomplish dehumidification merely involves the raising of the air temperature in the space being dehumidified. This does not remove any moisture from the air, but it does lower the relative humidity (see Fig. 14-4). Because of the relatively high temperatures normally required, dehumidification by heating is usually impractical.

The operation of controlled humidity storage facilities, both land and shipboard, is discussed in detail in Refs. 1 and 2, along with data on preparation of materiel for storage and inspection procedures during storage term.

14-2 DESICCANTS

Numerous materials are available as desiccants for moisture control. Some of these materials are silica gel, clay, alumina, bauxite, charcoal, calcium sulfate, and zeolites. Of these, silica gel and clay are the most commonly used in present military packaging.

Silica gel is an amorphous form of silicon dioxide. It is synthetically manufactured to a uniform grain and capillary size. Clay is a complex structure of natural crystalline and amorphous materials. Both desiccants are inert and have a high adsorption capability and rate. The adsorption is a result of capillaries in the materials, which attract water vapor, condense it, and hold it as a liquid by surface adsorption and capillary condensation.

Zeolites, commonly known as molecular sieves, are crystalline metal aluminasilicates and have been known as naturally occurring minerals for many years. Natural sources, however, are scarce and it has been only recently that molecular sieves have been synthesized and commercially produced. Because of their recent emergence, their application in military packaging has been limited. Molecular sieves will probably have an increased use in the near future because of their adsorption capacity and rate which are higher than those of other desiccants. The higher capacity permits the use of smaller desiccant charges. However, this must be balanced off against the presently higher cost of the molecular sieve.

Desiccants used for static dehumidification must meet the requirements of MIL-D-3464 (Ref. 3). Desiccants furnished in compliance with MIL-D-3464 are supplied in bags of different sizes up to a maximum size of 80 units of desiccant per bag. Silica gel and clay meet the requirements of MIL-D-3464 but molecular sieves, because of their large grain size, do not presently meet this specification.

Desiccants for dynamic dehumidification are produced under MIL-D-3716 (Ref. 4) and are supplied in bulk form. Silica gel, clay, and molecular sieves are all acceptable desiccants under the requirements of this specification.

The moisture adsorption rate of desiccant is not uniform under all conditions, but depends on several variables such as: (1) the amount of moisture the desiccant has already adsorbed, (2) the ambient temperature, and (3) the humidity (vapor pressure) of the atmosphere. Because of this variable adsorption rate, and the varying abilities of different types of desiccants to adsorb moisture, the requirements of MIL-D-3464 are based on desiccant units rather than weight or volume. A desiccant unit is defined as that quantity of desiccant that in equilibrium at 25°C adsorbs 3.0 grams of moisture at 20 percent relative humidity and 6.0 grams of moisture at 40 percent relative humidity. The requirements of MIL-D-3464 are summarized in Table 14-1. Fig. 14-5 shows two packages with the desiccant in place.

Desiccants specified under MIL-D-3464 and MIL-D-3716 must be capable of being reactivated after use. Reactivation consists of heating the desiccant to a sufficiently high temperature to drive off accumulated moisture. The reactivation temperature varies with the

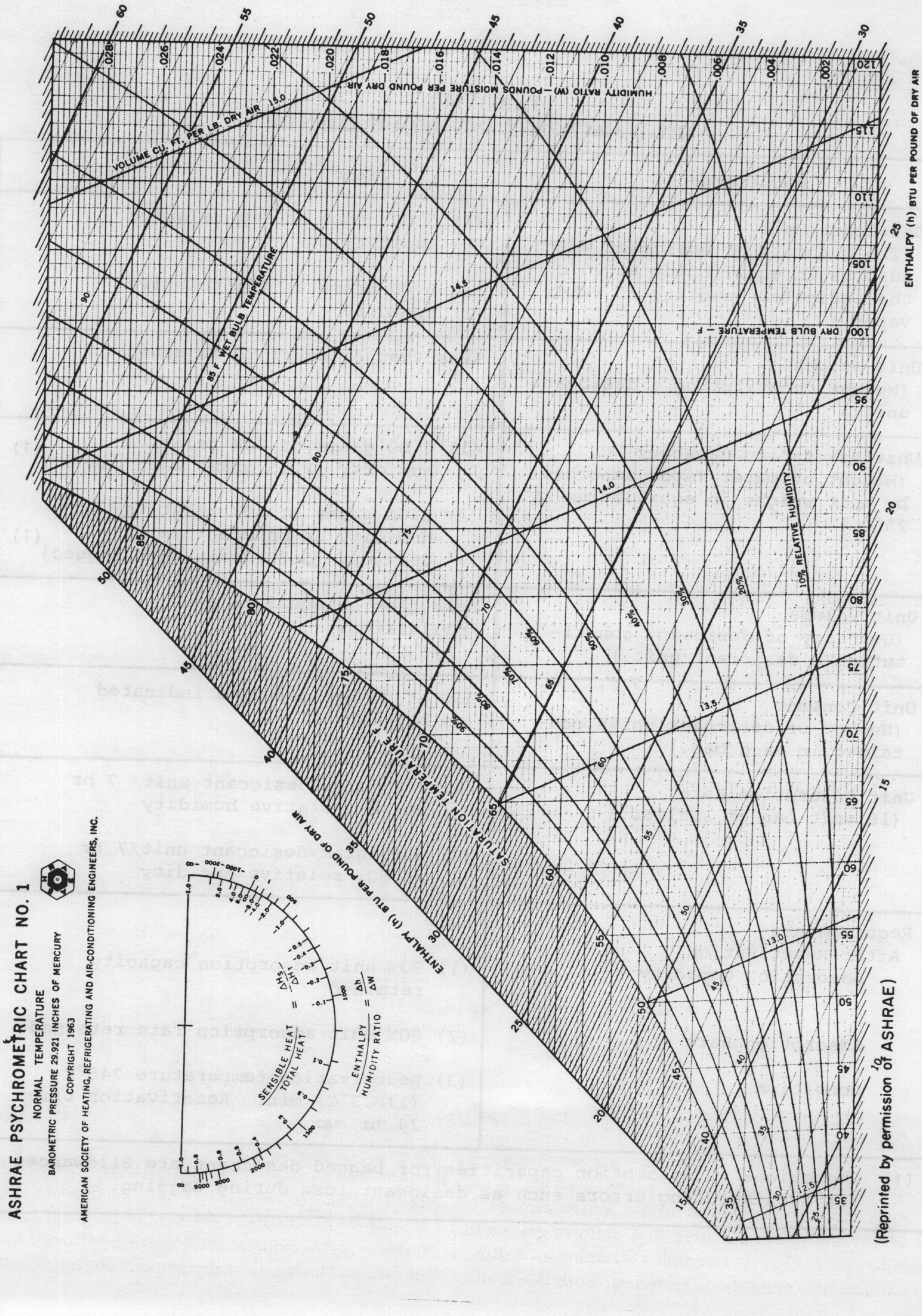


Fig. 14-4. Psychrometric Chart

TABLE 14-1
MIL-D-3464 DESICCANT REQUIREMENTS[3]

Requirements	Value
Desiccant Unit (The quantity of desiccant which adsorbs in equilibrium at 25°C the indicated quantity of water vapor.)	(1) 3.00 grams at 20% relative humidity (2) 6.00 grams at 40% relative humidity
Unit Weight (Weight constituting a desiccant unit.)	Less than or equal to 50 grams
Unit Adsorption Capacity (Weight of water vapor adsorbed by unit weight in equilibrium at 25°C.)	(1) 3.00 grams at 20% relative humidity (2.85 grams when bagged)(1) (2) 6.00 grams at 40% relative humidity at manufacture for delivery (5.70 grams when bagged)(1)
Unit Volume (Quantity of desiccant constituting a desiccant unit.)	Less than or equal to 45.0 milliliters
Unit Content (Number of desiccant units contained in each bag.)	95% of number of units indicated on bag label
Unit Adsorption Rate (16 unit bag or smaller.)	(1) 0.25 gram/desiccant unit/ 7 hr at 40% relative humidity (2) 0.90 gram/desiccant unit/7 hr at 80% relative humidity
Requirements After Reactivation Adsorption Capacity	(1) 90% unit adsorption capacity retained
Adsorption Rate	(2) 80% unit adsorption rate retained
Condition	(3) Reactivation temperature 245°F (118.3°C) min. Reactivation time: 24 hr max.

(1) Reductions in adsorption capacities for bagged desiccant are allowances for manufacturing errors such as desiccant loss during bagging.

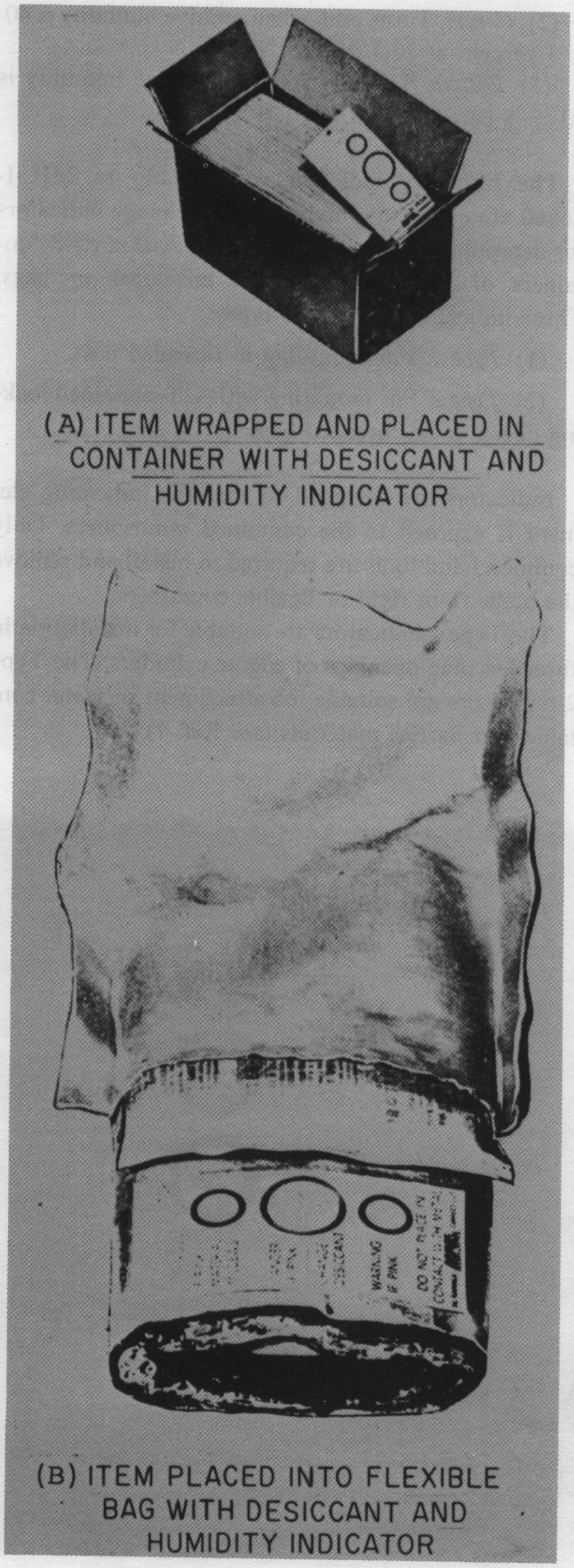


Fig. 14-5. Packages With Desiccant in Place

type of desiccant used. The reusable life of desiccant is limited by this heating and by the handling involved which cause physical deterioration of both the bag and the desiccant.

14-3 DESICCANT CALCULATIONS

To protect the contents of a package adequately against corrosion, it is imperative to provide a sufficient amount of desiccant to adsorb the initial moisture in the container materials, and in the air when the container is sealed; and to remove moisture during transportation and maintain a moisture-free environment during storage.

The relationships for determining the exact quantity of desiccant required for a specific application are difficult to determine accurately, but satisfactory empirical formulas–Eqs. 14-1 and 14-2–have been developed:

a. Units of desiccant for use within barrier other than sealed rigid metal barrier:

$$U = CA + XD \tag{14-1}$$

b. Units of desiccant for use within sealed rigid metal barriers:

$$U = KV + XD \tag{14-2}$$

where

U = number of units of desiccant to be used
C = 0.011 when area of barrier is given in in.^{2}
C = 1.6 when area of barrier is given in ft^2
A = area of barrier in in.^{2} or ft^2
K = 0.0007 when volume is given in in.^{3}
K = 1.2 volume within barrier in in.^{3} or ft^3
V = volume within barrier in in.^{3} or ft^3
X = 8 for hair felt, cellulosic material (including wood), and other material not categorized below
X = 6 for bound fibers (animal hair,

synthetic fiber, or vegetable bound with rubber)

X = 2 for glass fiber

X = 0.5 for synthetic foams and rubber

D = pounds of dunnage (other than metal) within barrier.

14-4 HYGROSCOPIC HUMIDITY INDICATORS

Humidity indicators are included as a check on the condition of the dehumidified package. Humidity indicators used in military packaging include those conforming to MS-20003 and MIL-I-26860. Fig. 14-6 shows hygroscopic humidity indicators.

The humidity indicator conforming to MS-20003 is constructed of blotting paper on which are enclosed three sensitive areas. The three areas indicate the following information:

(1) *Top.* Turns pink when relative humidity is 50 $\pm$ 5 percent at 73.5 $\pm$ 2°F

(2) *Center.* Turns pink when relative humidity is 40 $\pm$ 5 percent at 73.5 $\pm$ 2°F

(3) *Bottom.* Turns pink when relative humidity is 30 $\pm$ 5 percent at 73.5 $\pm$ 2°F.

The humidity indicators conforming to MIL-I-26860 are externally mounted color-change indicators for determining the relative humidity within rigid containers or moisture-vaporproof envelopes or bags. These indicators are of two types:

(1) *Type 1.* For mounting in threaded boss

(2) *Type 2.* For mounting with self-contained locking device or in threaded boss.

Indicators are designed so that the indicating element is exposed to the contained atmosphere. Only common hand tools are required to install and remove the plugs from rigid or flexible containers.

The Type 1 indicators are suitable for installation in threaded plug openings of engine cylinders. The Type 2 indicators are suitable for attachment in metal containers or barrier materials (see Ref. 1).

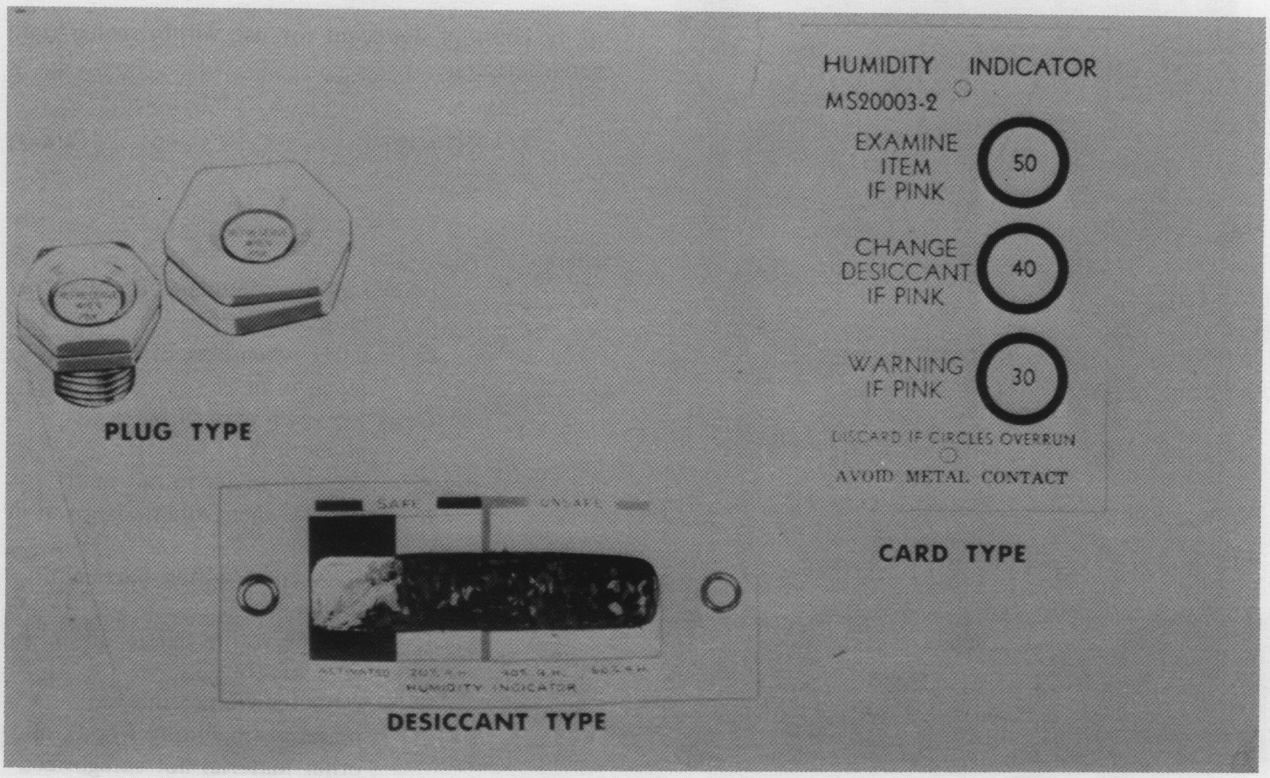


Fig. 14-6. Hygroscopic Humidity Indicators

14-5 ELECTRICAL HUMIDITY INDICATORS

In Method II packaging, the practical life of the element used to indicate humidity becomes extremely important. A method is required for sealing within the package a sensitive device capable of providing an indication of humidity inside the package over a relatively long period of time. One of the methods incorporated for this method of packaging is the electrical humidity indicating system.

Briefly, the system consists of an electrical sensing element assembly–composed of an electrical sensing element, a barrier seal, and an electrical conductor–which is incorporated as an integral part of the Method II package at time of fabrication. The electrical conductor extends from within the package through the vaporproof barrier to the outside of the exterior container. By use of a portable indicating instrument, determination of the moisture level can be made by contact with the electrical conductor on the container. Fig. 14-7 shows examples of electrical humidity indicators with sensing units adaptable to monitoring humidities in closed containers.

14-6 HUMIDITY INDICATOR AND CONTROL SYSTEMS

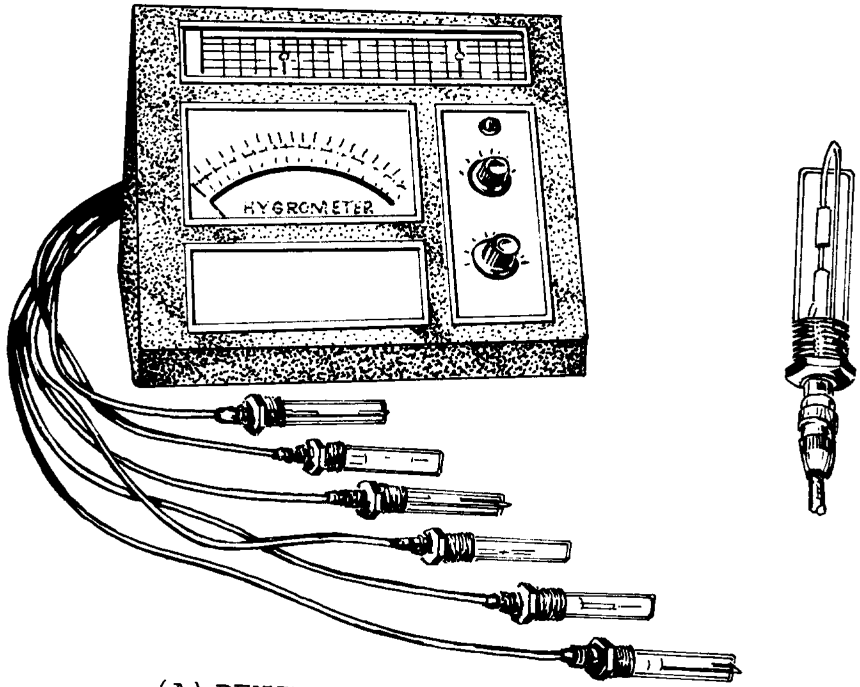
The atmosphere of storage facilities using dynamic dehumidification should be continuously checked to insure the maintenance of proper storage conditions. This can be accomplished by a monitor and recorder system linked to sensor devices. In this system, two pens mark a spring or electrically driven chart. One sensor element drives one pen to record humidity while a second sensor drives the other pen to record temperature. The system provides a continuous record of humidity and temperature during the storage term. Fig. 14-8 shows examples of recording instruments.

Humidity sensing and driving devices may be of the capacative type, hygroscopic film type, or hygroscopic hair type. Temperature sensing devices are usually bimetal strips or thermistors (temperature sensitive resistors). These same types of sensors can also be used to actuate humidistats or thermostats to operate the humidity and temperature control equipment.

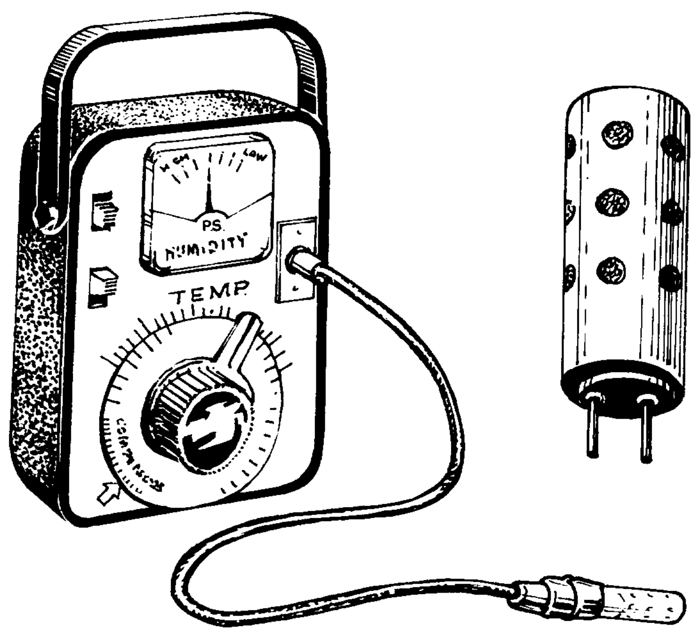
Indicator and control system sensors should be checked periodically for accuracy by comparing their readings with those of laboratory grade hygrometers. The dry- and wet-bulb temperatures obtained from the hygrometer are interpreted on a psychrometric chart (Fig. 14-4) to obtain the true relative humidity value. Fig. 14-9 shows examples of hygrometers.

14-7 PREPOSITIONED MATERIEL

Prepositioned materiel is combat ready materiel which is stored in a location as close as possible to its probable point of use. For this materiel to be combat ready, maintenance and storage procedures must provide adequate protection against deterioration and require a minimum of time and labor for depreservation. To reduce the time and labor, the materiel must be in as close to an operational condition as possible, requiring no reassembly, unpacking, or extensive removal of preservatives. One of the methods of accomplishing this state of readiness is controlled humidity storage. Storage under such conditions requires little other protection. Preparation of materiel for prepositioned storage is covered in Ref. 1. The methods of humidity control discussed in this chapter are applicable to prepositioned materiel.

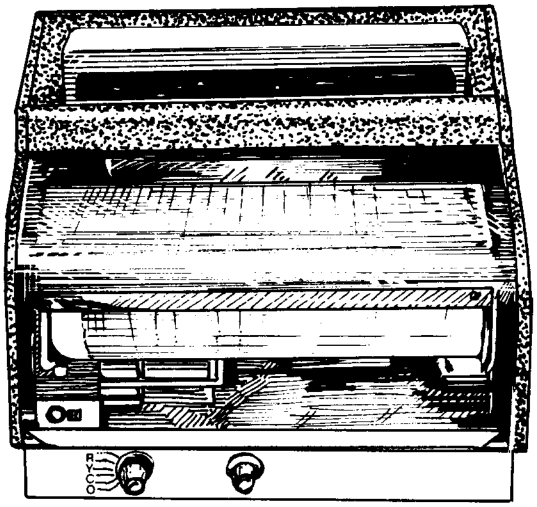


(A) BENCH MODEL WITH
CAPACITIVE SENSOR

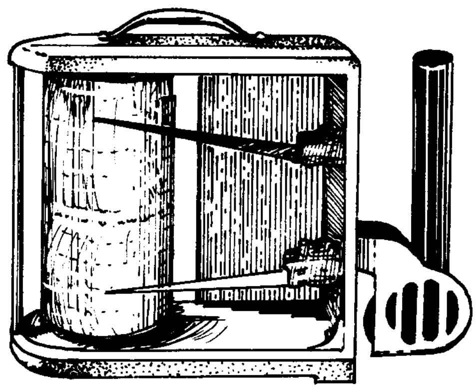


(B) PORTABLE MODEL WITH
HYGROSCOPIC FILM SENSOR

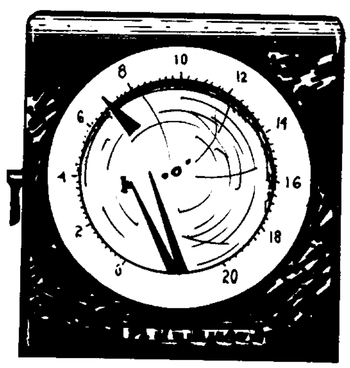
Fig. 14-7. Electrical Humidity Indicators



(A) LINEAR CHART



(B) DRUM CHART



(C) CIRCULAR CHART

Fig. 14-8. Humidity Recording Instruments

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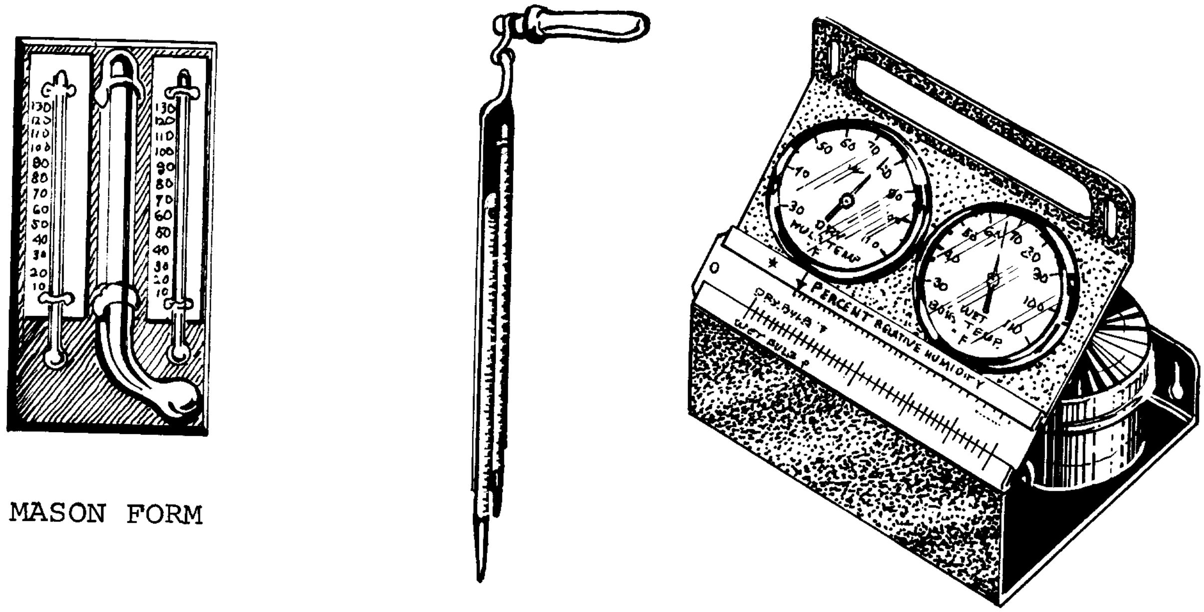

(A) MASON FORM

(B) SLING PSYCHROMETER

(C) DIAL INDICATING TYPE

Fig. 14-9. Hygrometers

REFERENCES

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2. TM 38-230-1, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I.
3. MIL-D-3464, *Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification.*
4. MIL-D-3716, *Desiccants, Activated for Dynamic Dehumidification.*
5. MIL-I-26860, *Indicator, Humidity, Plug, Color Change.*

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CHAPTER 15

TRANSPORTATION ENVIRONMENTS

The most damaging environments encountered by packaged items during transportation are shock and vibration. The shocks and vibrations to be expected depend on the particular mode of transportation. The effect of these environments on the item being transported is further dependent upon the manner in which the item is packaged and the stowage technique used. Techniques used for protecting packaged items against the harmful effects of shock and vibration include: blocking and bracing; use of cushioning materials, either elastic (resilient) or nonelastic (crushable); and use of shock and vibration isolation systems.

15-1 SHOCK AND VIBRATION

Although shock and vibration are often treated as separate phenomena, the distinction between the two is not clear cut. The difference between transient shock motion and periodic vibration is fairly obvious; but the existence of any basic differences between shock and random vibration, which is not periodic, is much less obvious. However, shock may be considered as intermittent excitation and vibration as sustained excitation.

Vibrations and shocks will impose forces on and deform any flexible or elastic structure. The severity of the deformation depends upon the nature and intensity of the imposed force, and the geometrical configuration, total mass, internal mass distribution, stiffness distribution, and damping of the item or equipment.

15-1.1 VIBRATION

Vibration is an oscillation wherein the quantity is a parameter that defines the motion of a mechanical system. Vibration has also been described as the variation, usually with time, of the magnitude of a quantity with respect to a specified reference, when the magnitude is alternately greater and smaller than the reference. Vibration may be periodic in nature, or it may be nonperiodic.

15-1.1.1 Periodic Vibration

The simplest form of periodic vibration is simple harmonic motion which is motion that varies sinusoidally. Simple harmonic motion can be identified by any two of the four parameters; frequency, amplitude of excursion, velocity, and acceleration. Fig. 15-1 shows the relationship among frequency, acceleration, and double amplitude, where double amplitude is the excursion from one extreme of harmonic motion to the other. From the illustration it can be seen that if double amplitude remains constant, the acceleration increases as the square of the increase in frequency. Likewise, increasing the excursion while the frequency remains constant results in a proportionately higher acceleration.

Any periodic motion can be considered as consisting of motions at one or more frequencies, with the motion at each frequency being harmonic. A periodic, or steady-state, vibration can be completely defined by designating the frequency, or frequencies, the maximum value of the harmonic variable at each frequency, and the phase relationships that exist between the component harmonic motions. The harmonic variable may be expressed in terms of displacement, velocity, or acceleration.

15-1.1.2 Nonperiodic Vibration

There are two types of nonperiodic vibration: random and white-noise. They differ from one another, although the two terms are often used synonymously. Random vibration differs from steady-state vibration in that the amplitudes at the component frequencies vary randomly with respect to time, and therefore cannot be predicted. White-noise vibration has no defined component frequencies, and both frequencies and amplitudes may vary randomly with time (Ref. 1).

15-1.1.3 Resonance

The response of a structure to shock and vibration is determined largely by the excitation frequency and resonance characteristics of the structure. Resonance

affects the magnitude of the applied load and its transmission characteristics. Any shock or vibration at the resonant frequency is amplified in force, resulting in an increased chance for damage.

The ratio of the output vibration amplitude to the applied vibration amplitude is the transmissibility. Transmissibility can be considered a magnification factor, and is greatest at resonance. It decreases down to unity below resonance, and can become less than unity above resonance.

15-1.2 SHOCK

Shock connotes impact, collision, or blow, usually caused by physical contact. It denotes a rapid change of load, or a rapid change of acceleration with a resultant change of load.

A shock motion cannot be defined by assigning numerical values to established parameters; it can only be defined by describing the history of a significant parameter such as acceleration, velocity, or displacement. The time duration of a shock pulse is important

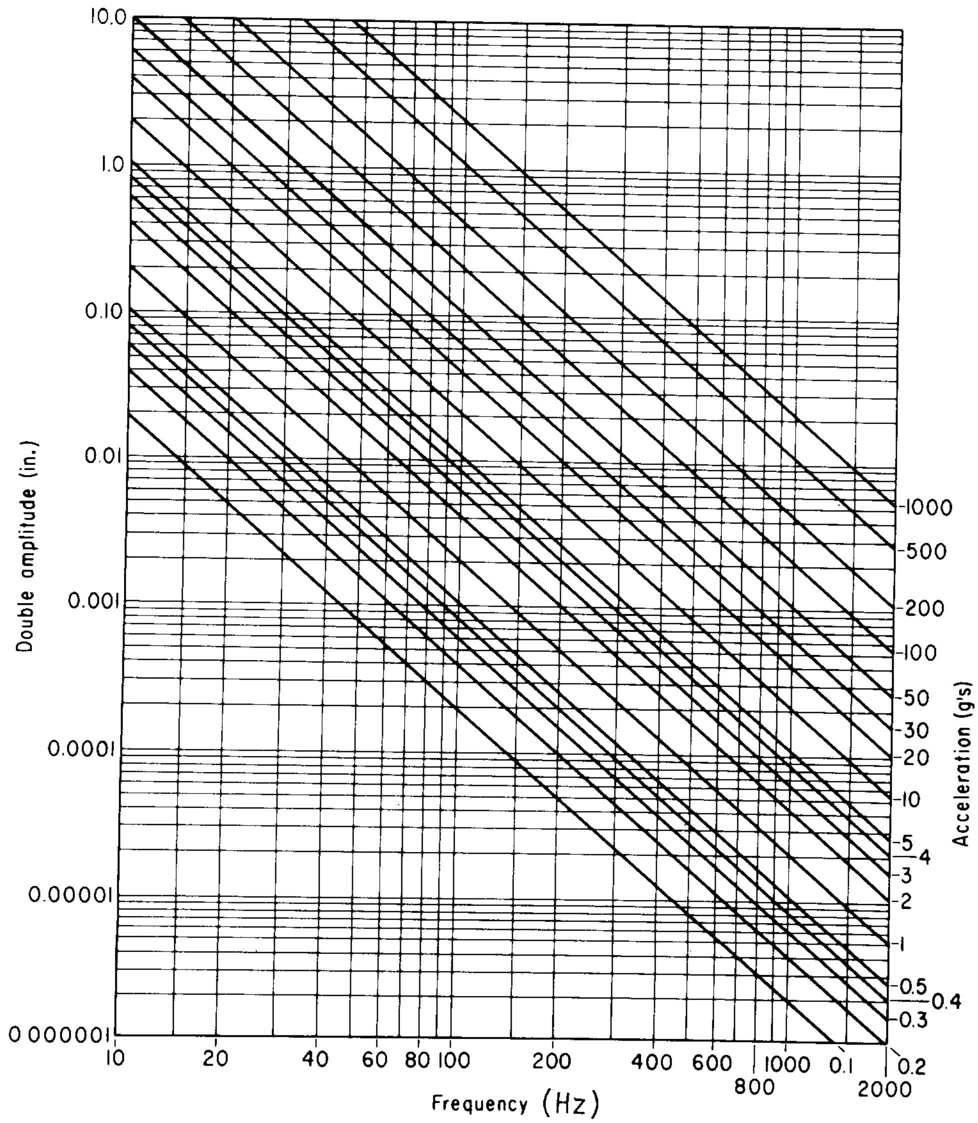


Fig. 15-1. Relationship Among Frequency, Acceleration, and Double Amplitude[1]

since it helps in determining the way in which an object will react to that pulse.

Although theoretically an equation might be written for a particular shock motion, actual shock motions are usually complex, and the customary method of describing the time function of the motion is graphical (Fig. 15-2). There are an infinite number of possible shock motions since the motion may vary in pulse shape, time duration, and peak acceleration (Refs. 1 and 2).

15-2 TRANSPORTATION SHOCK AND VIBRATION

Data on the actual shock and vibration environment likely to be encountered during the various modes of transportation are presented in the paragraphs which follow. Some of the data given are relative in nature, but are nevertheless useful in damage prevention.

15-2.1 TRUCK TRANSPORT

Vibration frequencies in motor trucks are dependent upon the natural frequency of the unsprung mass on the tires, the natural frequency of the suspension system, and the natural frequencies of the body structure. The vibration amplitudes are dependent upon road conditions and the speed of travel. Intermittent road shocks of high magnitude can occur, with resultant extreme truck-body displacements. These large displacements may result in a severe shock environment for unlashed cargo as it bounces about the truck floor. Vibrations caused by the truck engine and transmission system are relatively insignificant in the cargo area (Ref. 1).

The predominant natural frequencies of various military transport vehicles, as measured in the cargo space, are given in Table 15-1. Fig. 15-3 presents vibration data measured in the cargo spaces of trucks and trailers, and Table 15-2 shows the accelerations of the cargo in a 2-1/4-ton, M104 Trailer Combination during operation over various terrain.

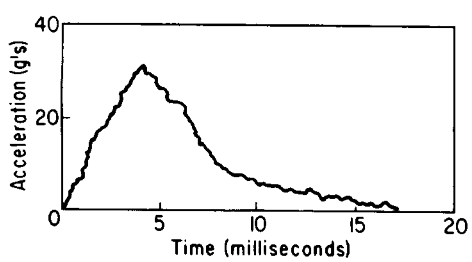


Fig. 15-2. Plot of Typical Shock Motion

15-2.2 RAIL TRANSPORT

Vibrations in moving freight cars arise from track wheel irregularities, and occur principally in the lateral and vertical directions. The exciting frequencies caused by rail joints and wheel imbalance vary from 0 to 13 Hz. Railroad car structural-frame frequency is usually in the range of 50 to 65 Hz. Shock and transient vibrations during coupling and during starting and stopping are generally considered to be the most damaging phase of rail shipment.

Fig. 15-4 presents data on the number of occurrences of shocks of various levels recorded on the floor of a freight car during a 700-mile trip. The data are divided into shock ranges and direction. For each direction and within each shock range, the shocks are plotted against the speed range during which they occurred. Table 15-3 shows the percentage of travel time in each speed range during the 700-mile trip. The time durations of the shock impulses, while not measured accurately, were estimated to be between 10 and 50 msec.

Fig. 15-5 shows the velocity of impact during switching operations taken from a representative number of railroad yard operations. It can be seen that the mean speed of impact is about 7 mph, which is well above the approximate 5 mph limit for which the switching gear provides cushioning protection. Longitudinal accelerations of a freight car body that can be expected for impact speeds of 1 to 7 mph are shown in Fig. 15-6.

The method of bracing greatly affects the maximum acceleration of lading. This is shown in Table 15-4. Although a freely-floating lading is desirable, it is not practical since it requires large space for the movement of the load; furthermore, it does not provide protection against several successive impacts in the same direction. Controlled floating, in which movement is controlled by means of snubbers that center the load after each impact, is the most practical. Fig. 15-7 shows the comparative results for one such controlled-floating arrangement and a blocked arrangement (Ref. 3).

15-2.3 AIR TRANSPORT

During air transport, the in-flight shock and vibration environment is generally not too severe. The loadings which are important are the dynamic loadings that occur during flight in rough air. These are differentiated from shock loadings in that they consist of fairly high magnitude accelerations imposed for a prolonged period of time. These accelerations can be as high as 2 to 3 g's during normal operation of large transport aircraft.

The most damaging conditions encountered during air shipment are the shocks resulting from handling operations. This is shown in Fig. 15-8, which is a plot of the maximum shocks recorded during a test shipment by a major airline. For the test, two impact recorders were placed in a wooden box, having a total weight of 73 lb, and both longitudinal and vertical shocks were recorded.

15-2.4 SHIP TRANSPORT

The principal excitation forces for shipboard vibrations result from the ship structure interfacing with the flow of water from the propellers, and from imbalance or misalignment of the propeller shaft system. The frequency range of the vibrations is about 5 to 25 Hz, with attendant accelerations reaching a maximum of 1 g.

During normal service ship cargos do not experience shock loads of any significant magnitude, with the exception of the shocks that occur during loading and unloading operations.

TABLE 15-1
PREDOMINANT FREQUENCIES MEASURED IN CARGO SPACES OF VARIOUS MILITARY TRANSPORT VEHICLES[1]

Type of Vehicle	Direction of Acceleration	Predominant Frequencies Hz		
		Springs	Tires	Body
Truck (2-1/2 tons)	Vertical	2 to 4	8 to 13	70 to 180
	Longitudinal	-	10 to 20	70 to 100
	Lateral	2	10 to 20	100 to 200
Truck (3/4 ton)	Vertical	2 to 3	5 to 10	60 to 110
	Longitudinal	-	-	70 to 100
	Lateral	-	-	60 to 70
Trailer (1 ton)	Vertical	3 to 5	8 to 10	50 to 100
	Longitudinal	-	-	50 to 100
	Lateral	2	-	50 to 120
M-14 Trailer	Vertical	1 to 4	7 to 10	50 to 70
	Longitudinal	3 to 4	8 to 10	200 and greater
	Lateral	2 to 4	-	-
Ml, 2T Trailer	Vertical	2.5 to 5	7.75 to 10.5	100 to 150

TABLE 15-2
CARGO ACCELERATION IN 2-1/4-TON TRUCK, M104 TRAILER COMBINATION[3]

Operation Over	Maximum Acceleration, g's			
	Longitudinal	Lateral	Vertical	Vector Total
Sandy Beach	2.5	1.0	4.5	5.3
Ungraded Road (30 mph)	0.5	1.0	1.5	1.9
Graded Road (30 mph)	1.0	0.25	1.0	1.4

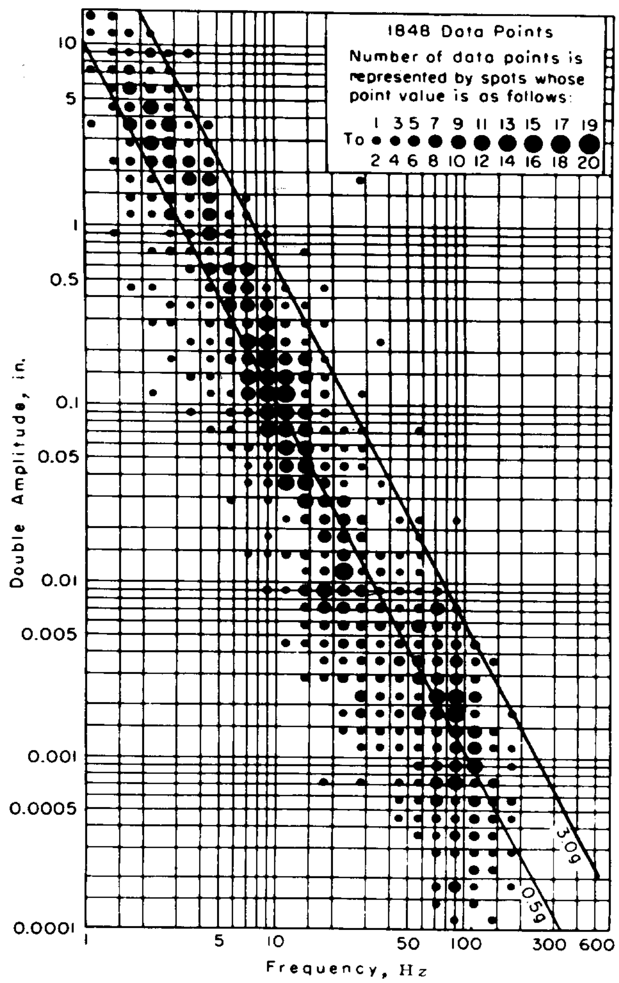
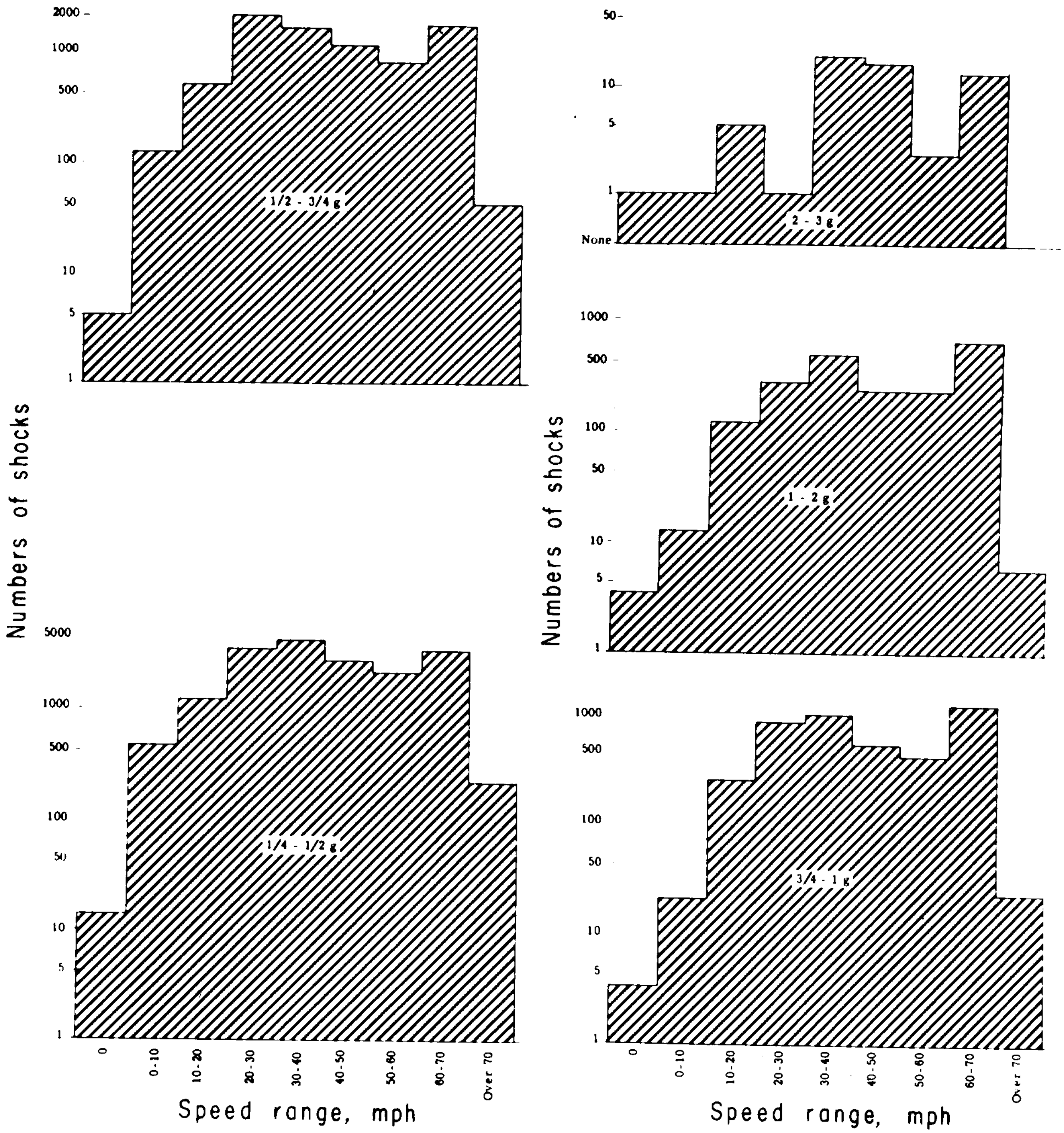
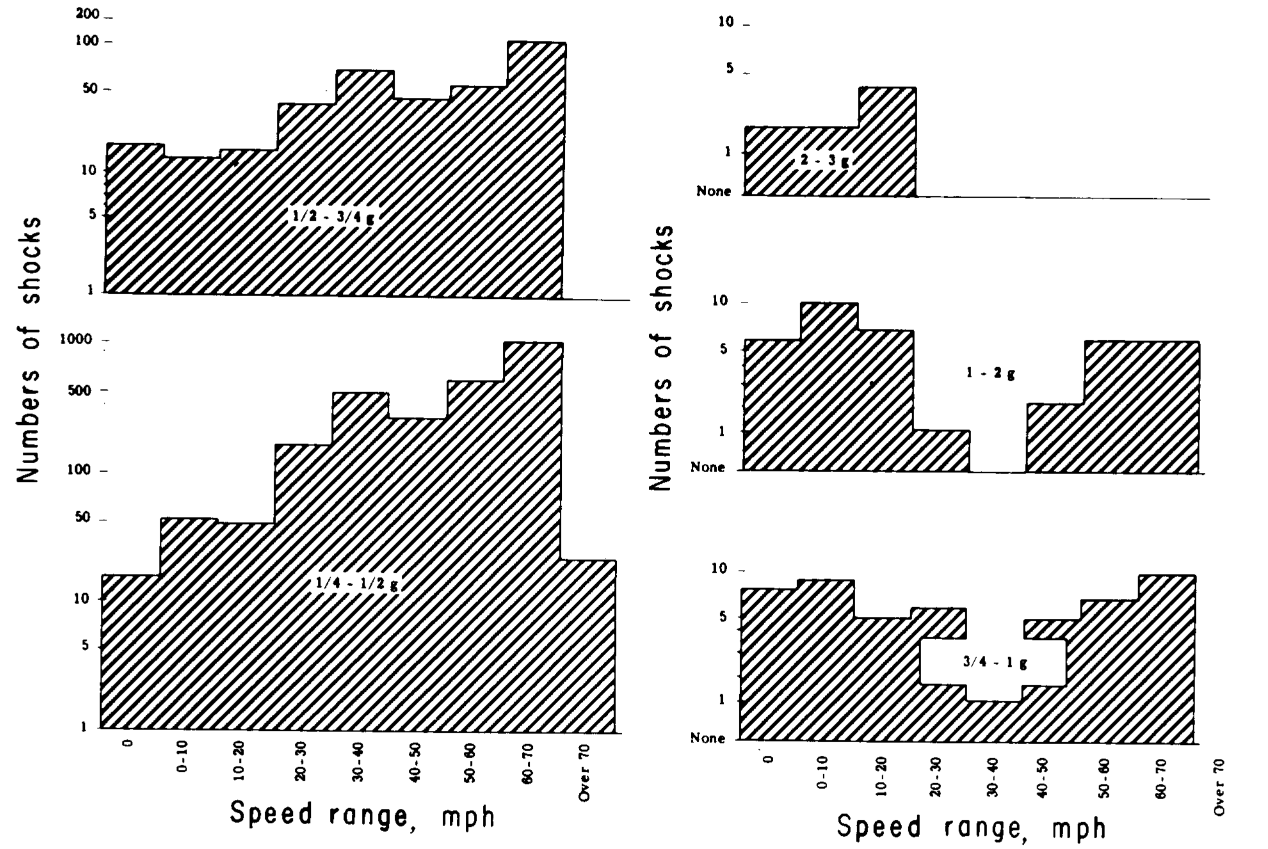


Fig. 15-3. Truck Transportation Vibration Data[1]

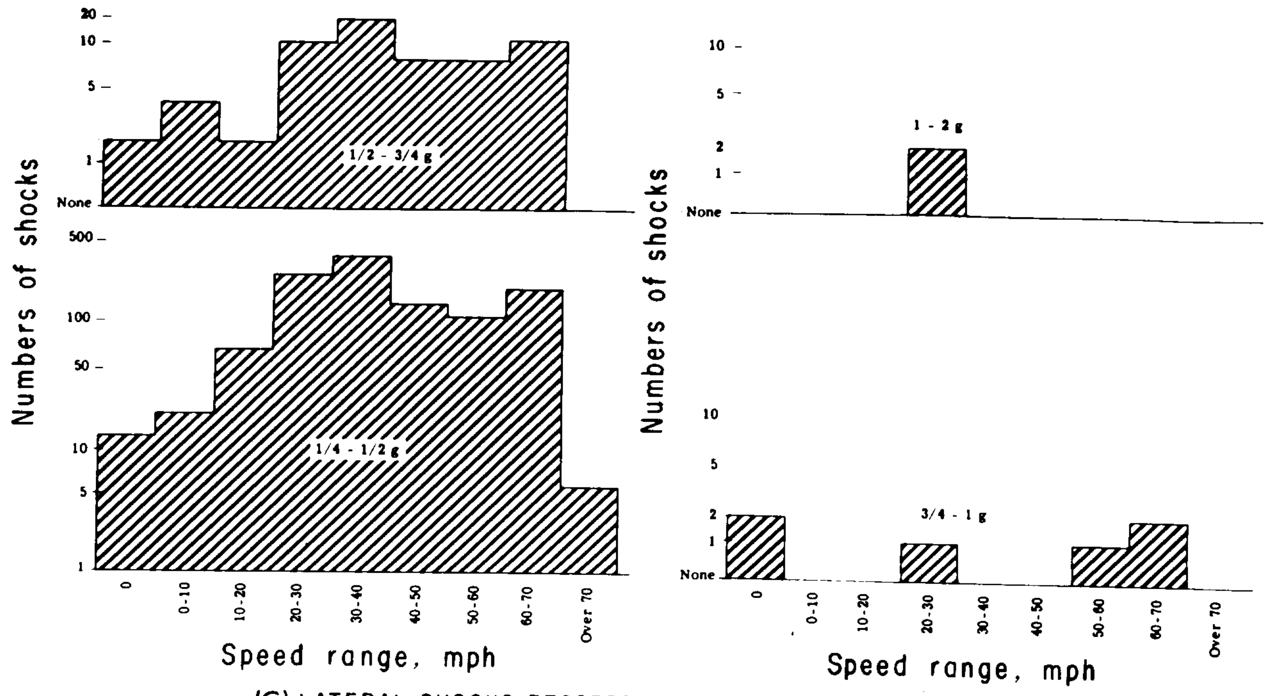


(A) VERTICAL SHOCKS MEASURED ON FREIGHT

Fig. 15-4. Freight and Freight Car Shock Measurements[1]



(B) LONGITUDINAL SHOCKS MEASURED ON FREIGHT CAR FLOOR



(C) LATERAL SHOCKS RECORDED ON FREIGHT CAR FLOOR

Fig. 15-4. Freight and Freight Car Shock Measurements[1] (Cont.)

TABLE 15-3
PERCENTAGE OF TRAVEL TIME VS SPEED RANGE FOR FIG. 15-4

Speed Range, mph	Travel and Recording Time, %
0	9.3
0-10	14.3
10-20	9.4
20-30	20.3
30-40	21.2
40-50	10.8
50-60	6.1
60-70	8.3
over 70	0.3

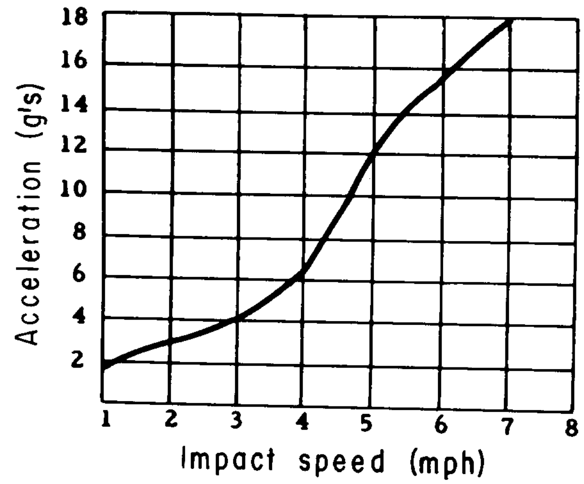


Fig. 15-6. Maximum Longitudinal Acceleration of Freight Car Body vs Switching Impact Speed[1]

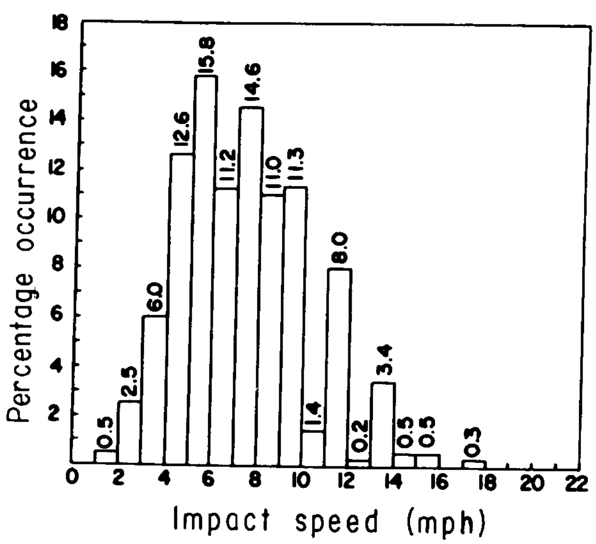


Fig. 15-5. Impact Speed During Freight Car Switching Operations[1]

TABLE 15-4
RATIO OF LADING ACCELERATIONS TO CAR ACCELERATIONS FOR DIFFERENT TYPES OF BRACING[3]

Type of Bracing	Ratio: $\frac{\text{lading acceleration}}{\text{car acceleration}}$
Solid Bracing	1.0
Controlled Floating	0.6-0.7
Free Floating	0.1

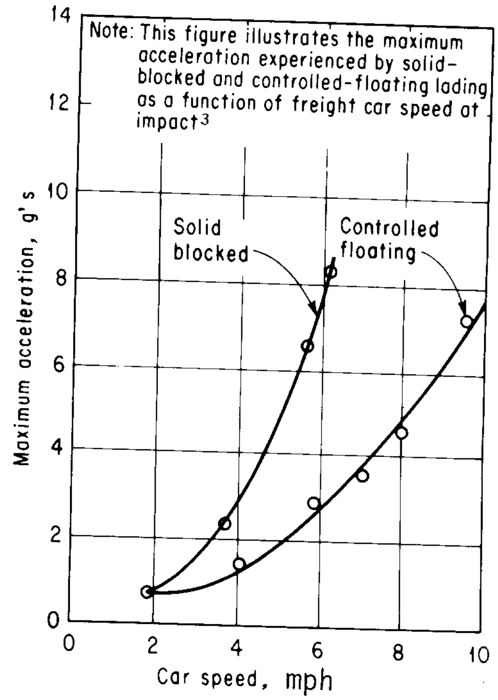


Fig. 15-7. Acceleration Experienced by Solid-blocked and Controlled-floating Lading

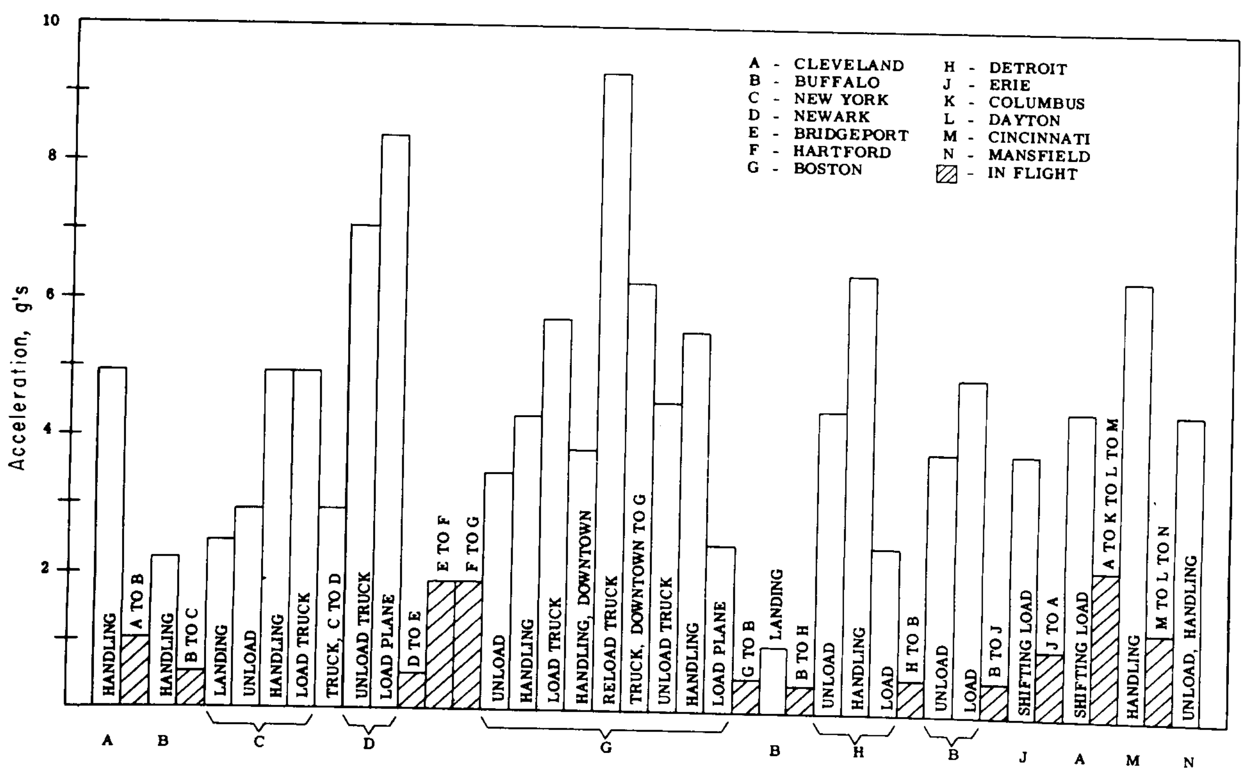


Fig. 15-8. Maximum Shocks Recorded During Airline Test Shipment[1]

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CHAPTER 16

NATURAL ENVIRONMENTS

16-1 CLIMATIC CONDITIONS

Climatic conditions vary widely from point to point over the surface of the earth. Furthermore, at any particular location daily as well as yearly variations in these conditions occur, and in many instances the variations are extreme. It is beyond the scope of this handbook to present detailed information on weather conditions around the world. Studies of the frequency of occurrence of climatic extremes on a regional basis have been completed within the Army to provide guidance for realistic consideration of climatic conditions in the research and development of materiel. Data from these studies pertinent to military packaging are included in the paragraphs which follow. For additional information on environment, refer to AMCP 706-115, *Basic Environmental Concepts* (Ref. 8).

16-1.1 WORLD-WIDE CLIMATIC EXTREMES

World-wide climatic extremes are presented in Fig. 16-1. Knowledge of these extremes is useful to military designers and testers as background information but, since the extreme values occur so infrequently, they are not normally used for design and test criteria.

16-1.2 CLIMATIC EXTREMES FOR MILITARY MATERIEL

Climatic extremes for consideration in the reasearch and development of materiel are specified in Quadriparite, Department of Defense, and Army documents (Refs. 1, 2, 3). Ref. 3 is the most recent of these documents and includes a map which shows the areas of occurrence of eight climatic categories set forth in the AR. Although not specifically intended for application to packaging, the map and the associated explanatory material are included here (Fig. 16-2) since they are the best available information on the regional occurrence of climatic extremes of concern in the field of military packaging. Included on the map are graphs which show the diurnal cycles of extreme temperature and humidity conditions in the indicated areas of occurrence of the eight climatic categories.

Areas of Occurrence of Climatic Categories, Fig. 16-2, shows the land areas where the climatic categories apply. The following discussion of the delimitation of the climatic categories and application of the map is included to avoid misinterpretation of the data and misuse of the map.

a. *Category 1, Wet-warm, and Category 2, Wet-hot.* The areas designated as Wet-warm and Wet-hot are the humid tropical regions of the world. Wet-warm conditions occur under the forest canopy and Wet-hot conditions occur in the same area, but in the open. Both Wet-warm and Wet-hot areas are differentiated on the basis of occurrence of the conditions. In the areas identified on the maps as "Non-seasonal", the conditions can be expected to occur at any time during the year, whereas in the areas identified as "Seasonal", they occur only during the rainy season. In the "Seasonal" areas, temperatures higher than the 95°F Wet-hot limit may occur during the dry season. For example, in most of Southeast Asia, Wet-hot conditions prevail during the wet monsoon season, but during the dry monsoon season, the higher temperatures associated with Intermediate Hot-dry conditions apply.

b. *Category 3, Humid-hot Coastal Desert.* The desert areas on the immediate coast of the Persian Gulf and Red Sea designated as Humid-hot are characterized at times by relatively high temperature (100°F) combined with extremely high amounts of water vapor in the air near the ground (dew point 86°F). Occasionally, higher temperatures occur in these areas, but not in combination with as high a humidity.

c. *Category 4, Hot-dry.* The areas designated as Hot-dry were delimited on the basis of the occurrence of high temperatures. During the hottest month in a normal year, the temperature may be expected to be above the Intermediate Hot-dry extreme of 110°F, and are expected to be hotter than 125°F no more than one percent of the time in the most extreme part of the area.

d. *Category 7, Cold, and Category 8, Extreme Cold.* The areas designated as Cold and Extreme Cold

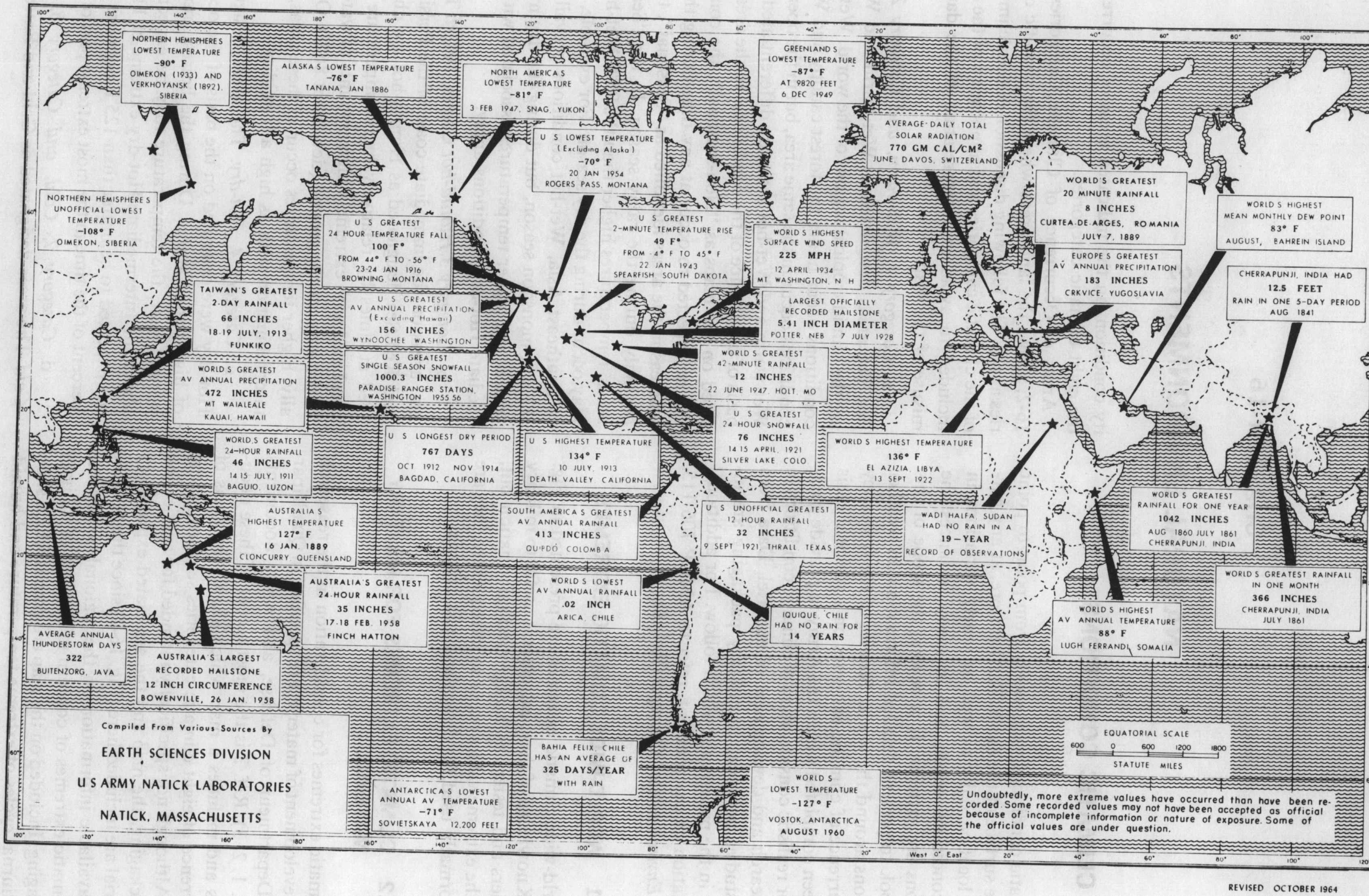


Fig. 16-1. Weather Extremes Around the World

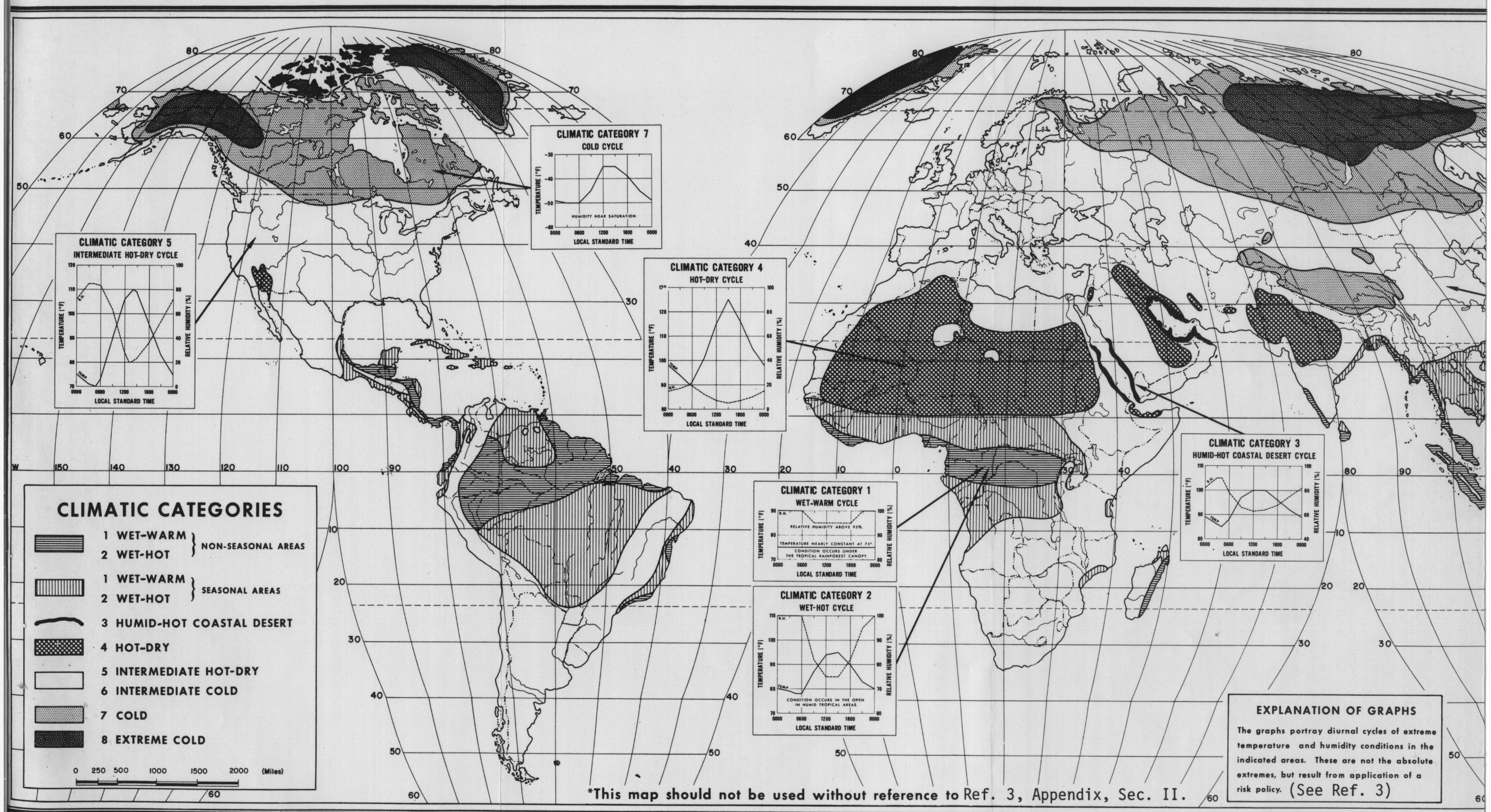
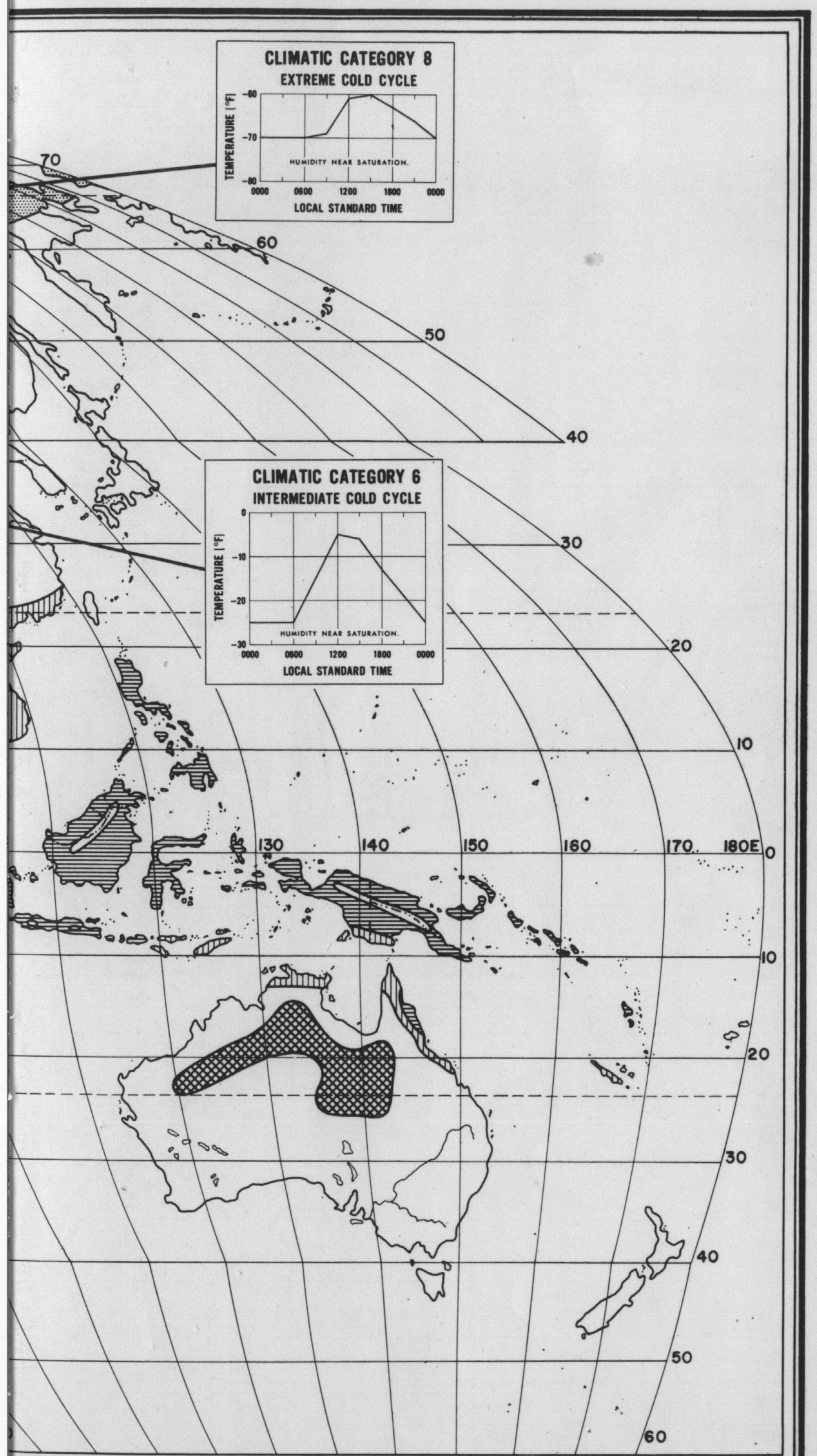


Fig. 16-2. Areas of Occurrence of Climatic Categories*[3]



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were delimited on the basis of the occurrence of low temperatures. In the Cold areas, temperature during the coldest month in a normal year may be expected to be colder than the Intermediate Cold extreme of −25°F, but colder than the Cold extreme of −50°F for no more than one percent of the time in the most extreme part of the area. In the Extreme Cold areas, temperature during the coldest month in a normal year may be expected to be colder than the Cold extreme of −50°F but colder than −70°F no more than one percent of the time in the most extreme part of the area.

e. *Category 5, Intermediate Hot-dry, and Category 6, Intermediate Cold.* Intermediate Hot-dry and Intermediate Cold conditions apply in the area which remains when the other climatic categories are delimited. Intermediate Hot-dry conditions occur primarily near the boundary of the Hot-dry category, and Intermediate Cold conditions occur near the boundary of the Cold category. Temperatures warmer than 110°F and colder than −25°F are rare in the Intermediate areas. Parts of the area with Intermediate conditions are not subject to high temperatures or to low temperatures. Fig. 16-2 is a summary showing the daily cycles of temperature, solar radiation, and relative humidity applicable for each climatic category. Induced storage and transit conditions are included. For a complete discussion of the derivation of the conditions in each category, Ref. 3 should be consulted; however, a brief excerpt of explanatory material follows:

a. *Category 1, Wet-warm.* Wet-warm conditions are found under the canopy of heavily forested tropical areas. The extreme feature of the category is the long duration of high relative humidity at moderate temperatures.

b. *Category 2, Wet-hot.* Wet-hot conditions are found in the same general areas where Wet-warm conditions occur, but in the open rather than under the forest canopy. Wet-hot conditions characterized by high temperatures accompanied by high humidities and intense solar radiation may be found outside the areas designated in Fig. 16-2, but only for short periods in a season of three months or less.

c. *Category 3, Humid-hot Coastal Desert.* Humid-hot Coastal Desert conditions are limited to the immediate coasts of bodies of water having a high surface temperature such as the Persian Gulf and the Red Sea. These areas experience very large amounts of water vapor associated with the air near the ground. The high temperatures, high humidities, and intense solar radiation of these areas comprise a stress which must be recognized for men and some classes of materiel.

d. *Category 4, Hot-dry.* Hot-dry conditions are found in the deserts of Northern Africa, the Middle East, West Pakistan and India, the Southwest United States and Northern Mexico, and Australia. These are the hottest areas of the world with accompanying intense solar radiation, but humidities are normally low and dryness is an additional problem.

e. *Category 5, Intermediate Hot-dry, and Category 6, Intermediate Cold.* The inclusion of these categories results from Army policy that many general-purpose items of military equipment need not be designed to withstand the extremes of the hottest, and/or coldest, categories, but rather may be designed to withstand less extreme intermediate conditions which are experienced in the more populated areas of the world. Therefore, many military items are designed to withstand the Category 5 maximum temperature of 110°F and the Category 6 minimum temperature of −25°F,

f. *Category 7, Cold, and Category 8, Extreme Cold.* These two categories of cold are set forth in Ref. 3 to afford flexibility in the design of material for use in cold areas. Cold conditions with a minimum temperature of −50°F occur throughout a relatively large area in the Northern Hemisphere north of 45°N latitude and away from moderating maritime effects. Extreme Cold conditions with a minimum temperature of −70°F are found in relatively remote areas of North America and Eurasia (Antarctica is excluded from consideration by international agreement).

16-2 OTHER NATURAL ENVIRONMENTAL FACTORS

In addition to the climatic hazards (Fig. 16-3), other natural environmental factors are of concern to the packaging engineer. These factors are covered in the paragraphs which follow.

16-2.1 ALTITUDE (PRESSURE AND TEMPERATURE)

Both atmospheric pressure and temperature vary widely with altitude. Nominal values of both, which can be considered for application to packaging, are given in Table 16-1. These values were determined from data in Ref. 4 which should be consulted for more definitive information. The figures are the best estimates available at the one percent level–i.e., estimates that lower temperatures and pressures can be expected no more than one percent of the time. Seasonal and geographical variations in pressure and temperature exist but can be neglected for packaging purposes.

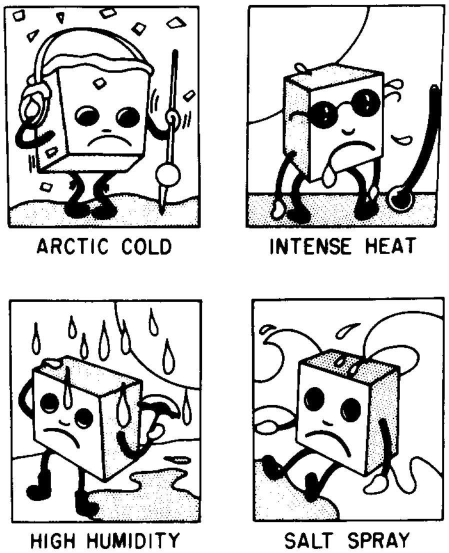

Fig. 16-3. Climatic Hazards Encountered by Military Packages

The reasons for considering altitude are: (1) materiel is transported through mountain passes where the temperatures and pressures for elevations as high as 15,000 ft may apply, and (2) materiel transported by air may be subjected to temperature and pressure which exist at 50,000 ft should there be a failure of cabin environmental regulation.

16-2.2 BLOWING SAND, DUST, AND SNOW

During transport or outdoor storage, packaged items may experience an environment of blowing sand, dust, or snow. If the item is such that its operation would be impaired by an accumulation of these small particles, the package must shield against their penetration. Furthermore, the package material must withstand the erosive effect of the particles.

Design criteria for blowing sand, dust, and snow are presented in Table 16-2. No data are given for the abrasive characteristics of the various particles since this depends on their hardness and shape.

16-2.3 WIND LOADING

Wind loading, which is the force exerted by wind on exposed objects, can sometimes cause damage to packages and packaged items. Strong winds can tear loose canvas or other protective coverings used for outdoor storage. It can also interfere with handling operations by blowing over containers, and making the loading and unloading of vehicles hazardous. Wind loading can be especially severe during transport by open conveyance, as a result of the increase in relative wind speed due to motion of the vehicle.

Wind speeds presently specified for military design purposes are given in Table 16-3. The actual force exerted on an object by the wind is a function of the square of the wind speed and its direction, and the frontal area and configuration of the object. For objects of simple shape a flat surface perpendicular to the direction of the wind, the force F can be calculated using the equation

$$F = C_N S \left(\frac{\rho V^2}{2}\right) \quad (16\text{-}1)$$

where

F = force, lb
C_N = shape factor, dimensionless

TABLE 16-1
NOMINAL VALUES OF TEMPERATURE AND PRESSURE VS ALTITUDE

Height or Elevation, ft	Pressure, mb	Temperature, °F
10,000	660	-42
15,000	520	-53
20,000	410	-68
30,000	255	-87
40,000	160	-98
50,000	100	-105

TABLE 16-2
DESIGN LIMITS FOR BLOWING SAND, DUST, AND SNOW[2,3]

Item	Limit
Blowing Sand	Particles 0.01 to 1.0 mm in diameter, with predominant diameters between 0.15 and 0.3 mm Wind 40 mph (35 knots) at height of 5 ft Sand concentration, 10 lb per ft cross section distributed with few grains at 5 ft height and two-thirds of grains lower that 1 in. Sand stirred up by aircraft or vehicles may produce heavier concentration at higher levels.
Blowing Dust	Particles 0.0001 to 0.01 mm in diameter with a concentration of 6 x 10^{-9} g/cc. Dust stirred up by aircraft or vehicles may produce heavier concentrations. Dust velocity of 40 mph (35 knots) at height of 5 ft
Blowing Snow	When blown by strong winds, snow crystals are broken and abraded in roughly equidimensional grains with rounded or subangular corners. Particles occur in greatest numbers in size range of 0.02 to 0.4 mm diameter. Smaller sizes tend to occur at lower temperatures.

S = area perpendicular to wind, ft^2
ρ = air density, slug/ft^3
V = wind velocity, fps

In the case of a flat plate, which corresponds to one face of a square or rectangular box or package, C_N varies between 1.16 and 2.0. This variation is shown in Fig. 16-4, where a and b are the dimensions of the side or face perpendicular to the wind flow. For more intricately shaped objects, the value of C_N can be obtained from standard reference works, such as Ref. 5.

16-2.4 OZONE

Ozone is of concern to the packaging engineer because of its harmful effects on natural rubber and synthetic elastomers. Ozone (O_3) is a form of molecular oxygen. Any high-energy input to O_2 can cause the formation of O_3. At sea level the concentration of ozone in the atmosphere varies considerably with latitude, season of the year, local weather conditions, and availability of easily oxidizable gases, smoke, or other finely divided organic matter suspended in the air. Ozone concentrations are found to be exceptionally high when atmospheric conditions exist which favor the transmission of ozone from the upper atmosphere. Ozone is also generated by electrical equipment.

Limited data exist on the regional variation of ozone concentration at the earth's surface. Furthermore, much of the existent data are in disagreement. This is probably due to the fact that various measurements, although made at the same locations, were taken at different times and with different measuring devices.

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From the data available, average ozone concentration appears to vary from negligible amounts to about 0.06 part per million. At certain locations throughout the United States much higher concentration have been recorded. Concentrations of 0.2 to 0.3 part per million parts of atmosphere are not uncommon in these areas. The region of highest ozone concentration in the United States seems to be in the Los Angeles, California, area, with concentrations as high as 0.8 part per million having been recorded (Ref. 6) (Chapter 4).

16-2.5 MICRO-ORGANISMS

Most microbiological forms have an optimum growing temperature in the range of 59° to 95°F (15° to 35°C), although there are some forms that will grow at nearly 32°F (0°C) and others that will grow at very high temperatures. The average optimum conditions for fungi are a temperature of about 86°F (30°C) and a relative humidity of 95-100 percent. Below 70 percent relative humidity there is little opportunity for fungal growth.

TABLE 16-3
MAXIMUM WIND SPEEDS FOR MILITARY DESIGN PURPOSES[2,3]

	Ordinary *				Extreme **			
	Steady		Gusts		Steady		Gusts	
	MPH	*Knots*	*MPH*	*Knots*	*MPH*	*Knots*	*MPH*	*Knots*
Portable ***.........	40	(35)	60	(52)	60	(52)	90	(78)
Temporary †.........	50	(43)	75	(65)	70	(61)	105	(91)
Semi-Permanent††....	65	(57)	100	(87)	80	(70)	120	(104)

The above conditions apply to a height of 10 ft above ground. For wind speed at other heights, the ratio to that at 10 ft is as follows:

Height in Feet	2	5	10	15	25	50	75	100
Ratio to 10 ft wind..........	0.71	0.89	1.00	1.07	1.13	1.24	1.29	1.32

	Steady		Gusts	
	MPH	Knots	MPH	Knots
10 feet above the water ..	85	75	115	100

* Ordinary Conditions: applies to many inland areas

** Extreme Conditions: applies to mountain or coastal areas where storms of hurricane intensity occur

*** Life expectancy 2 yr
† Life expectancy 5 yr
†† Life expectancy over 5 yr

Although micro-organisms exist over a large part of the earth's surface, they are only a severe environmental problem in regions possessing the right combinations of temperature and relative humidity (Chapter 4).

16-2.6 RODENTS AND INSECTS

Little quantitative data can be specified concerning rodents and insects as part of a package environment. This is principally because of the wide variety of types and geographic distribution of these pests. Whenever it is suspected that rodents or insects might constitute a packaging problem, information can be obtained from documents such as Ref. 7. Rodents and insects are discussed in Chapter 4.

16-3 COMBINATIONS OF ENVIRONMENTAL FACTORS

Although they are dealt with individually in the preceding paragraphs, the natural environmental factors do not occur singly. Inherent properties of the atmosphere–such as temperature, humidity, and pressure–are present at all times. They interact with each other as well as with other natural environments that may be present. Consequently, when considering natural environmental factors from the standpoint of their effects, the manner in which each factor alters the effects of the others must be taken into account. To analyze the practical combinations of the factors, it is best to examine them in pairs. Then, any one of a pair can be paired off with another, and this process repeated to determine possible combinations.

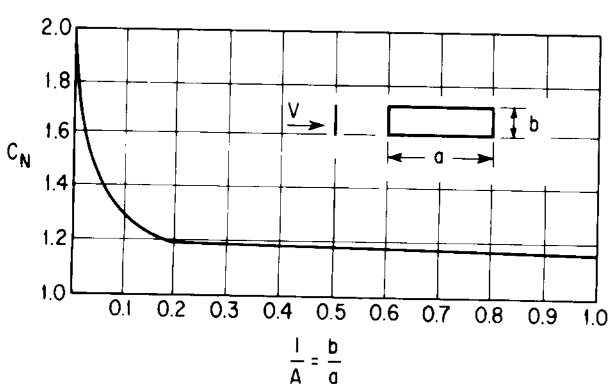

Fig. 16-4. Variation of Shape Factor C_N[5]

The combinations of these factors and the manner in which each combination may intensify, neutralize, or add nothing to the individual effects are:

a. *High Temperature and Humidity.* High temperature tends to increase the rate of moisture penetration. The general deterioration effects of humidity are increased by high temperatures.

b. *High Temperature and Low Pressure.* Each of these environments is dependent on the other. For example, as pressure decreases, outgassing of constituents of materials increases; and as temperature increases the rate of outgassing increases, hence, each tends to intensify the effects of the other.

c. *High Temperature and Salt Spray.* High temperature tends to increase the rate of corrosion caused by salt spray.

d. *High Temperature and Solar Radiation.* This is a natural combination that causes increasing effects on organic materials.

e. *High Temperature and Fungi.* A certain degree of high temperature is necessary to permit fungi and micro-organisms to grow; but, above 160°F (71°C), fungi and micro-organisms cannot develop.

f. *High Temperature, and Sand and Dust.* The erosion rate of sand and dust may be accelerated by high temperature. However, high temperatures reduce sand and dust penetration.

g. *Low Temperature and Humidity.* Absolute humidity normally decreases with temperature but low temperature induces moisture condensation, and, if the temperature is low enough, frost or ice.

h. *Low Temperature and Low Pressure.* This combination can accelerate leakage through seals, etc.

i. *Low Temperature and Salt Spray.* Low temperature reduces the corrosion rate of salt spray.

j. *Low Temperature and Solar Radiation.* Low temperature will tend to reduce the effects of solar radiation.

k. *Low Temperature, and Sand and Dust.* Low temperature increases sand and dust penetration.

l. *Low Temperature and Fungi.* Low temperature reduces fungi growth. At subzero temperatures, fungi will remain in suspended animation.

m. *Low Temperature and Ozone.* Ozone effects are reduced at lower temperatures, but concentration increases with the lower temperatures.

n. *Humidity and Low Pressure.* Humidity increases the effects of low pressure, particularly in relation to electronic equipment. However, the actual effectiveness of this combination is determined largely by the temperature of the environment.

o. *Humidity and Salt Spray.* High humidity may dilute the salt concentration, but it has no bearing on the corrosive action of the salt.

p. *Humidity and Fungi.* Humidity helps the growth of fungi and micro-organisms but adds nothing to their effects.

q. *Humidity, and Sand and Dust.* Sand and dust have a natural affinity for water, so this combination increases deterioration.

r. *Humidity and Solar Radiation.* Humidity intensifies the deteriorating effects of solar radiation on organic materials.

s. *Humidity and Ozone.* Ozone reacts with moisture to form hydrogen peroxide which has a greater deteriorating effect on plastic and elastomers than the additive effects of moisture and ozone themselves.

t. *Solar Radiation and Low Pressure.* This combination adds nothing to the overall effects.

u. *Solar Radiation and Fungi.* Because of the resulting heat from solar radiation, this combination probably produces the same combined effect as high temperature and fungi. Further, the unfiltered radiation is an effective fungicide.

v. *Solar Radiation and Ozone.* This combination increases rate of ozidation of materials.

w. *Fungi and Ozone.* Fungi are destroyed by ozone.

16-4 EXTERNAL VS INTERNAL PACKAGE ENVIRONMENT

The conditions existing inside of a closed package or container are not necessarily the same as the ambient environment. Internal package temperatures may be significantly higher than the ambient temperature and, if the package is sealed, external temperature variations result in changes in the pressure and relative humidity inside the package.

To determine the internal environment of a package, an engineering analysis must be carried out. The factor involved in this analysis are the external environment, the package material and configuration, and the conditions existing inside of the package at the time of packaging.

REFERENCES

1. Quadripartite Standardization Agreement 200, *Climatic Factors Affecting Design Criteria,* March 1969.
2. MIL-STD-210A, *Climatic Extremes for Military Equipment.*
3. AR 70-38, *Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions,* May 1969 (replaces AR 705-15, *Operation of Materiel Under Extreme Conditions of Environment).*
4. Marvin Diamond and Oskar M. Essenwanger, *Atmospheric Environmental Test and Design Criteria,* U.S. Army Electronics Research and Development Activity, White Sands Missile Range, N.M., September 1962.
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6. C. L. McDermit, *Tire Preservation Study,* ATAC Project MIU 60-1, U.S. Army Tank-Automotive Command, Warren, Michigan.
7. Glenn A. Greathouse and Carl J. Wessel, *Deterioration of Materials, Causes and Preventive Techniques,* Reinhold Publishing Corp., N.Y., 1954.
8. AMCP 706-115, Engineering Design Handbook, *Environmental Series, Part One, Basic Environmental Concepts.*

CHAPTER 17

TESTING AND INSPECTION

Military supplies and equipment must be protected against damage due to force and exposure. Since the prime objective of packaging is to extend the useful lifespan of an item, the protected item must remain in that state of protection without depreciation until it is placed into service. The paragraphs which follow illustrate the requirement for thorough and efficient inspection and test procedures.

17-1 DAMAGE MECHANISMS

a. *Force.* Damage may result from hazardous forces encountered in transportation, handling, and storage (Fig. 17-1).

(1) *Transportation hazards* involve forces encountered through rail, truck, boat, or air shipments. Damage can result from:

(a) Abrupt starts and stops

(b) Vibration and shock

(2) *Handling forces* involve those damaging forces received through loading, unloading, and handling during storage operations. Examples of handling where damage often occurs are:

(a) Manual handling–dropping and puncture

(b) Fork-lift truck handling–dropping and puncture

(c) Cargo nets–dropping, crushing, and wracking

(d) Grab hooks–crushing and puncture

(e) Slings–crushing, dropping, and wracking

(f) Conveyors–jarring, smashing, and dropping

(3) *Storage forces* involve those forces resulting from the crushing effect of superimposed loads through stacking.

b. *Exposure.* Exposure to the different climatic conditions and weather hazards–such as high humidity, rain, salt spray, extreme cold, dry intense heat, and the cycling of these weather conditions–will tend to accelerate the breakdown or deterioration of unprotected items. Moisture in its different forms is the main damaging factor in climatic exposure. Exposure hazards are controlled by preservation and packaging of the unit, and by using water-resistant exterior containers and waterproof or water-vaporproof barrier materials.

c. *Counteraction of Packs to Hazards.* Items which are packed properly will resist damaging effects of force and exposure.

(1) Force is counteracted by:

(a) Using rigid shipping containers

(b) Immobilizing the item within the container through anchoring, blocking, and bracing

(c) Damping forces through the use of cushioning materials

(d) Reinforcing shipping containers with metal and nonmetallic strappings

(2) Exposure is counteracted by the use of:

(a) Water-resistant shipping containers

(b) Waterproof and water-vaporproof barrier materials in various applications.

17-2 TYPES OF TESTS (Refs. 1 and 5)

An item packaged in accordance with a method of preservation as outlined in MIL-P-116 (Ref. 4) must be tested for a determination of the effectiveness of that

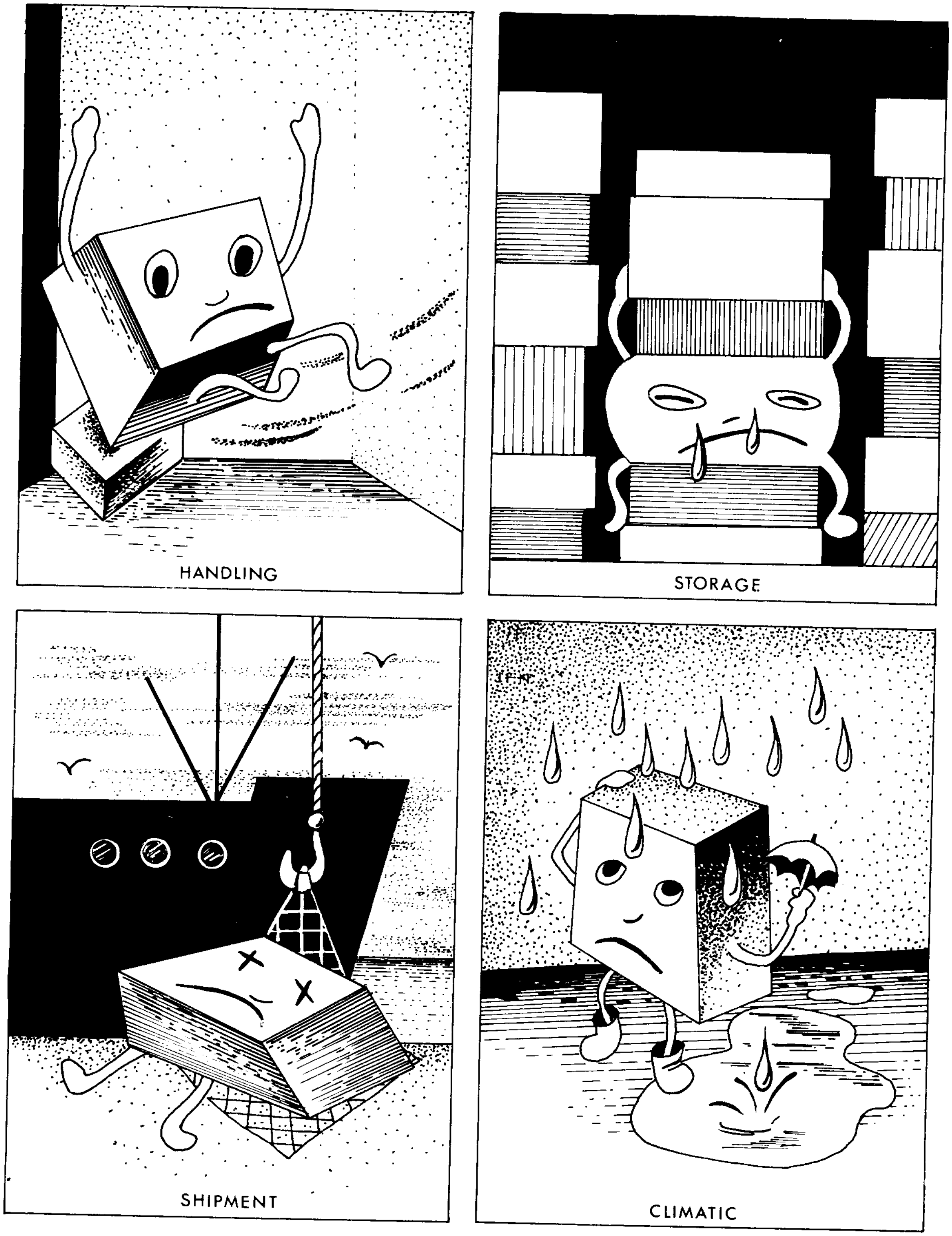


Fig. 17-1. Hazards Encountered by Military Packs

method. The type of test conducted is dependent on the packaging method used and as specified in MIL-P-116. Table III of MIL-P-116 states the specific tests for the various methods. To be acceptable, the packaging materials and the item within the unit package must show no signs of damage or operational malfunction due to deterioration as a result of a test.

Tests designed to evaluate the sealing and protective qualities of the packaging material, as well as the methods of packaging, are briefly outlined in the paragraphs which follow. Tests for evaluating the effectiveness of the package and material to resist the forces of handling, and continue to maintain their designed protective qualtities, are included. More detailed descriptions of these tests and procedures are discussed in MIL-P-116 and FED-STD-101.

17-2.1 VACUUM CHAMBER TECHNIQUE

Package test samples will be held at ambient conditions for at least four hours prior to testing. The sample bag, package, or can is submerged in water contained in a vacuum vessel, up to a maximum depth of 1 in. above the sample. A vacuum is then drawn within the following limits: (a) heat-sealed packages and metal containers, 8.5 in. of mercury; and (b) rigid containers other than all metal, 5.5 in. of mercury. The minimum elapsed time for this test, while under observation for leakage of air, is 30 sec. The sample must be inverted and tested again. Fig. 17-2 shows the vacuum chamber test configuration. A steady or recurring succession of bubbles from any surface or seam shall be cause for rejection.

17-2.2 HOT WATER TECHNIQUE

This test procedure will be used when the size or shape of the package precludes the use of the vacuum vessel. The test sample will be held at ambient conditions for at least 4 hr prior to commencement of testing. The package will be immersed no more than 1 in. below the surface, in water which has been heated to 50°F above the temperature at which the package was conditioned. The package is rotated so as to check each surface for air leakage. Observation of each seam and face of the package should be for at least 15 sec with a total elasped time not to exceed 8 min. A steady or recurring succession of bubbles from any seam or surface shall be cause for rejection.

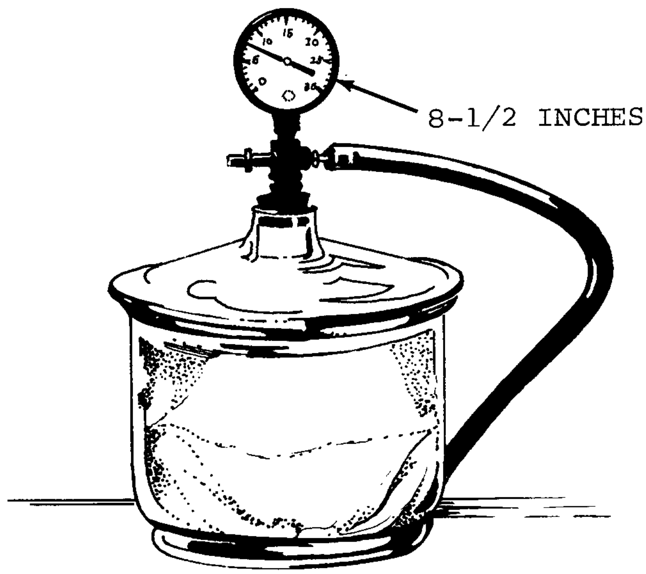


Fig. 17-2. Vacuum Chamber Technique for Heat Sealed Packages

17-2.3 SUBMERSION (OR IMMERSION) TECHNIQUE

Completed package is conditioned at ambient conditions for at least 4 hr prior to performance of the submersion test.When conditioning has been completed,the package is immersed for 1 hr in water at a temperature approximately 40°F cooler than the package. The package will be immersed no more than 2 in. below the surface of the water and not less than 1 in. After removal, the package is opened and inspected. There must be no evidence of moisture within the package. Fig. 17-3 depicts criteria for submersion test.

17-2.4 VACUUM RETENTION TECHNIQUE

The flexible barrier enclosing the item will be sealed except for an opening at one end to accommodate a tube connected to a vacuum producing apparatus. A vacuum of 5 ± 0.5 in. of water measured by gage or water manometer or 9 ± 1 mm of mercury, is drawn on the sealed package and the tube closed. Loss of vacuum as indicated by the measuring device will not exceed 25 percent of the original vacuum after remaining undisturbed for an elapsed time of 10 min. The vacuum retention test is depicted in Fig. 17-4.

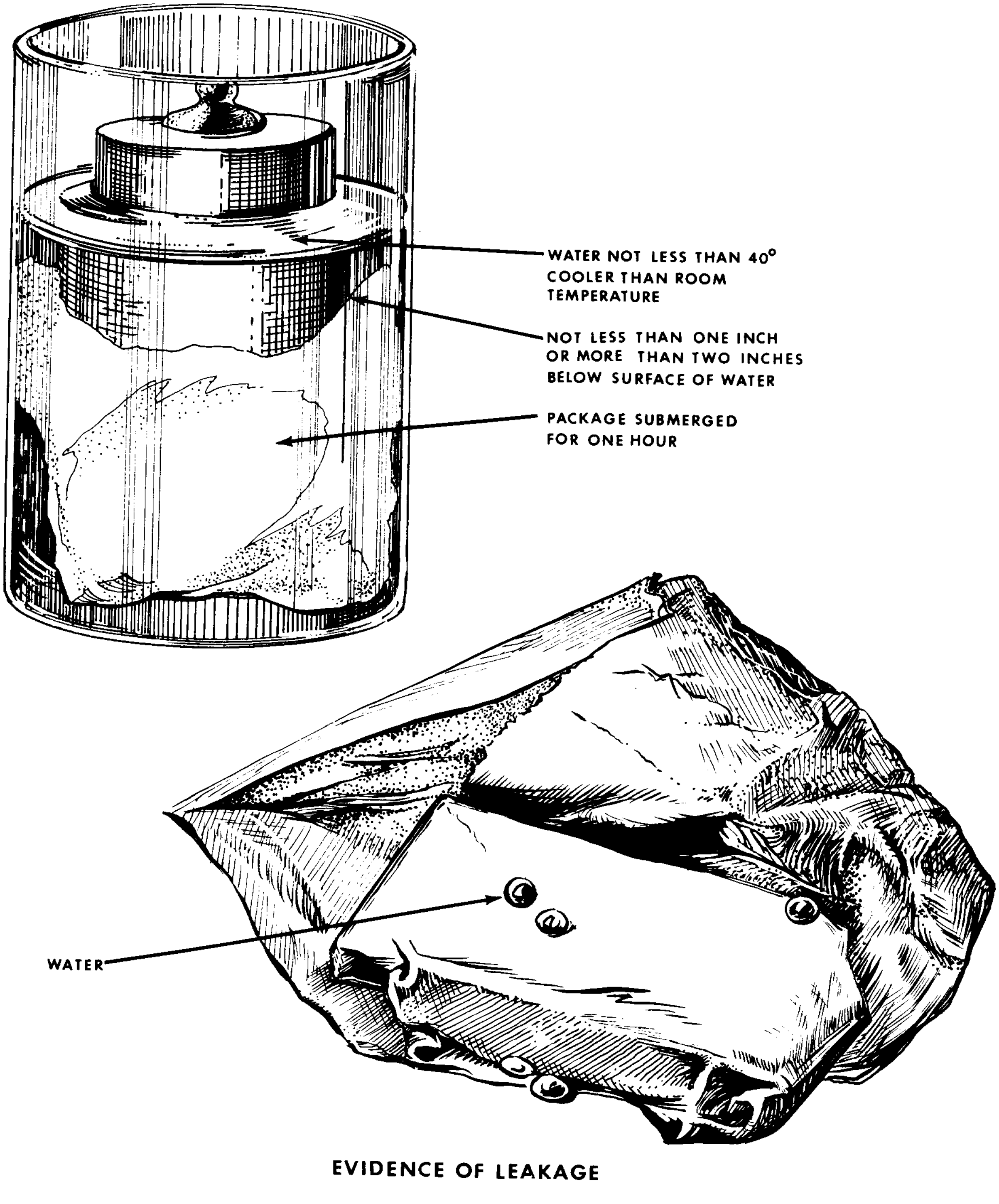


Fig. 17-3. Submersion Technique

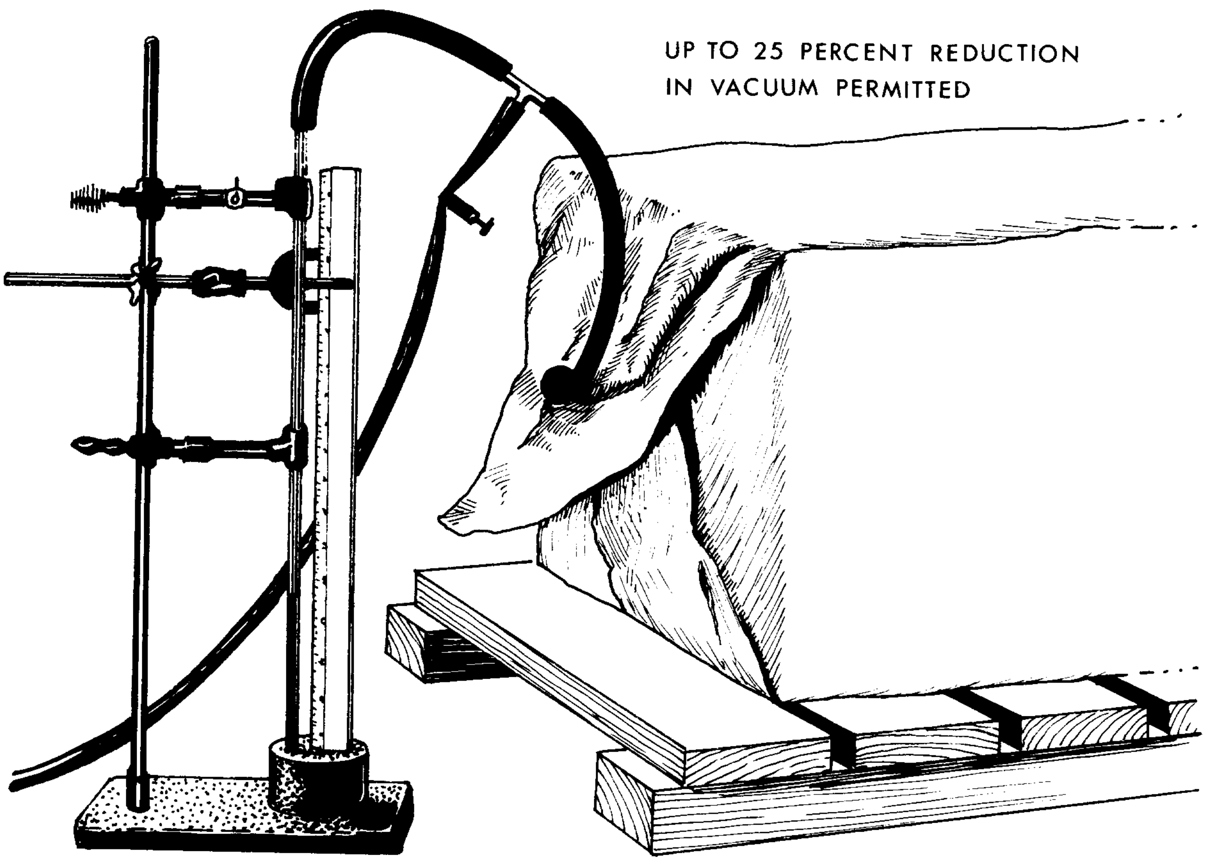


Fig. 17-4. Vacuum Retention Technique

17-2.5 PNEUMATIC PRESSURE TECHNIQUE

Through an air connection installed in the container wall, dry air is introduced to create an internal pressure of four or five pounds gage pressure per square inch. The air supply is then closed. Any loss of gage pressure over a 30 min period will be cause for rejection. Fig. 17-5 shows pneumatic pressure test details. Evidence of leakage is detected either by loss of pressure or by observance of air bubbles either during immersion of the pressurized container in water or after coating the outer surface of the container with a water-soap solution.

17-2.6 CYCLIC EXPOSURE TEST

Completed packages are given the cyclic exposure test A or B only when specified in the contract or order. Packages are allowed to stand undisturbed overnight in preparation for application of the test, and are subjected to the following continuous cycle of varying temperatures and water spray.

TEST A

Preparation for test
Overnight at 120° to 130°F

First day of test
Two hours of water spray at 50° to 60°F
Two hours at −10° to 0°F
Two hours of water spray at 120° to 130°F
Two hours of water spray at 50° to 60°F
Overnight at 35° to 50°F

Second day of test
Four hours at 120° to 130°F
Two hours of water spray at 50°to 60°F
Two hours at 35° to 50°F
Overnight at 120° to 130°F

Third day of test
Two hours of water spray at 50°to 60°F
Two hours at −10° to 0°F
Three hours at 35° to 50°F
Overnight at 120° to 130°F

TEST B

Preparation for test
Overnight at 120° to 130°F

First day of test
Two hours of water spray at 50° to 60°F
Four hours at 120° to 130°F
Two hours of water spray at 50° to 60°F
Overnight at 120° to 130°F

Second day of test
Same as first day

Third day of test
Same as first day

After completion of testing, the package is opened and examined. No evidence of moisture or corrosion is permitted.

17-2.7 HEAT-SEAL TEST

Sections of the heat seal 1 in. in width, cut perpendicular to the line of the seal, are taken from test specimens or package barriers. The section is then positioned between the jaws of testing clamps. A static load is applied slowly and uniformly without impact and allowed to act for a period of 5 min. Fig. 17-6 illustrates the heat seal test procedure. Partial separation of the heat seal is acceptable within the first 2 min of the test to allow areas of partial fusion adjacent to the actual seal to pull apart. Delamination of laminated barrier material after application of the static load will be cause for rejection. Any separation of the heat sealed area during the final 3 min of the test will be cause for rejection.

17-2.8 ROUGH HANDLING TESTS

The rough handling tests listed in Table 17-1 will be conducted in accordance with the applicable test methods specified in FED-STD-101 (Ref. 5). Graduated drop and impact tests heights will be as listed in Table 17-2. The particular tests employed usually depend upon the size, shape, and weight of the package. Completed packages as prepared for shipment are given the rough handling test when specified by contract or order. If the rough handling tests should be required, they will precede applicable tests specified to detect leaks, inadequate seals or closures, and preservation retention. Refer to Fig. 17-7 for the rough handling tests described in subsequent paragraphs. Applicable specifications should be consulted for details involving specific tests such as construction of test media, measurements, etc.

17-2.8.1 Vibration Test

Test packs are vibration tested on standard packaging laboratory vibration machines. The machines are variable in adjustment allowing control of the speed or number of cycles per minute and the type of motion desired. The duration of the test and the procedures for accomplishment are specified in ASTM Test Method D-999 and FED-STD-101 Methods 278 and 279. The effects of testing will frequently produce deterioration or partial crushing of the unit or interior packaging which reduces resistance to other shocks, such as impact from dropping, jolting, or bumping. This may also disclose weakness in assembly of the packed item. The tests simulate the forces and motions peculiar to railroad cars, motor trucks, aircraft, coolies, pack-saddles, etc. Both the item and the container shock mitigation systems and susceptibility to vibration induced damage must be considered. MIL-STD-810B and MIL-STD-1186, which are primarily concerned with the background item, should be consulted for additional guidance (Refs. 7 and 8).

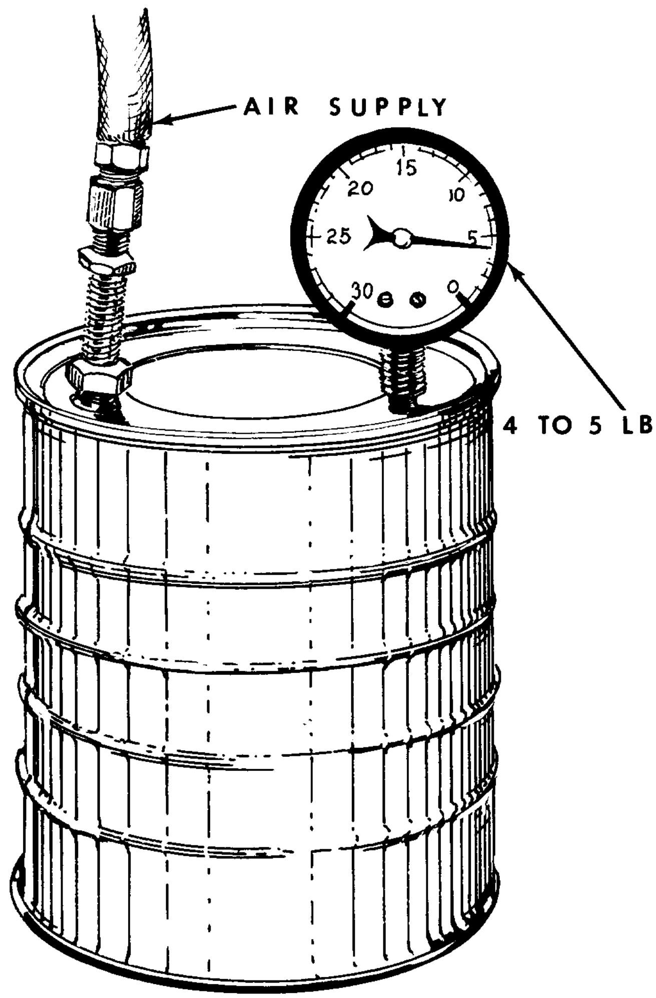
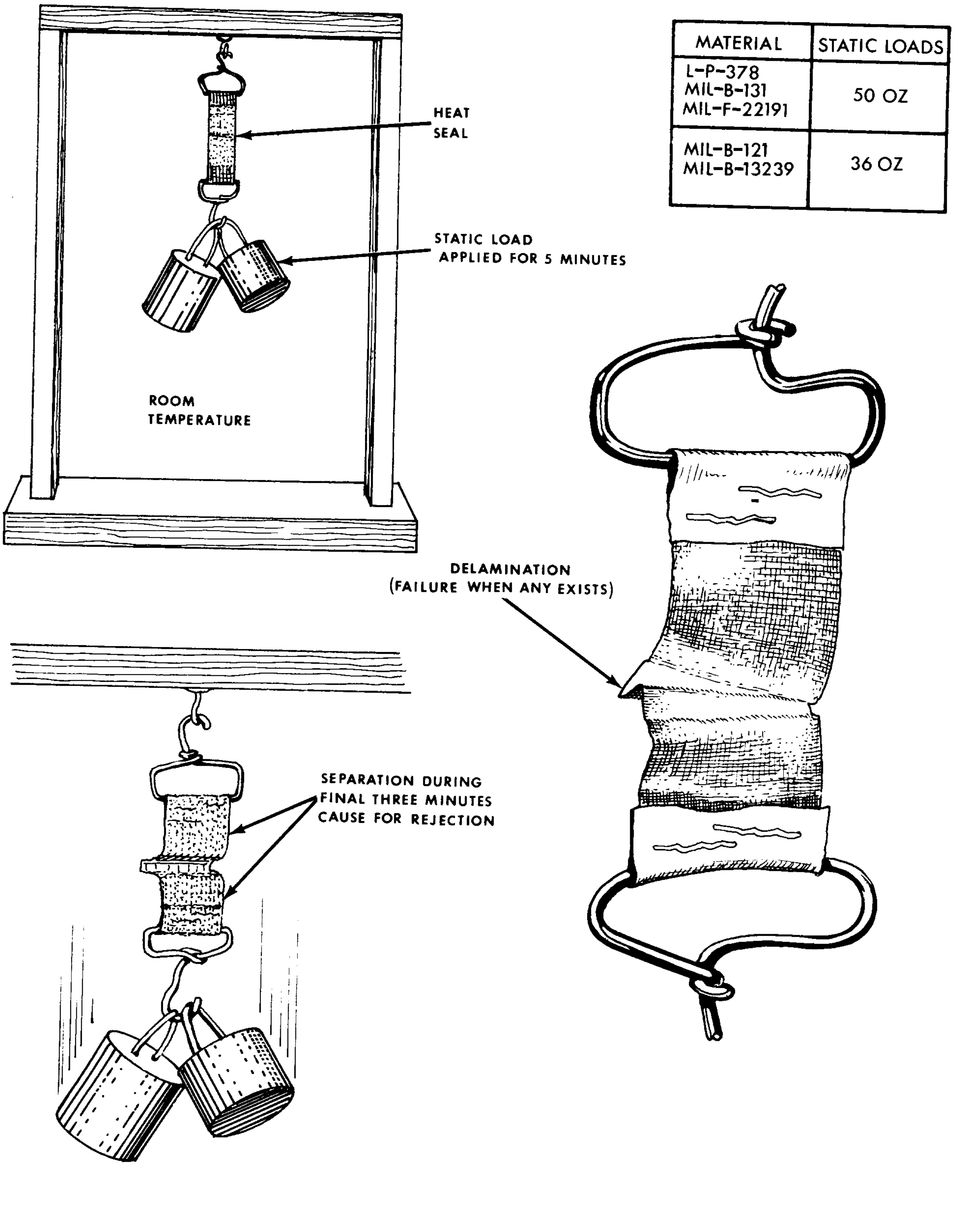


Fig. 17-5. Pneumatic Pressure Technique



MATERIAL	STATIC LOADS
L-P-378 MIL-B-131 MIL-F-22191	50 OZ
MIL-B-121 MIL-B-13239	36 OZ

Fig. 17-6. Heat Seal Test

TABLE 17-1
ROUGH HANDLING TESTS

Vibration test Compression test Incline-impact test Revolving drum test Drop test (Free-fall)	Edgewise-drop test Cornerwise-drop test Pendulum-impact test Simulated contents test

17-2.8.2 Compression Test

The compression test, when accomplished in accordance with ASTM D-642-47, provides information for measuring the ability of a container to resist external compressive loads applied to its faces, and the ability of a container to resist external compressive loads applied to diagonally opposite edges or corners. The containers are usually void of content during testing. These test procedures are suitable for boxes, crates, barrels, drums, kegs, and pails made of metal, wood, plastic, fiberboard, and combinations of these materials. This test is in accordance with FED-STD-101 Method 243.

17-2.8.3 Incline-impact Test

Test packs are mounted on a movable platform dolly which rides down a plane inclined 10 deg and strikes a fixed hard backstop. The dolly is released from a predetermined distance from the backstop and allowed to free-travel the distance down the incline. The impact shock is transmitted through the dolly to the package and simulates abuses encountered in freight cars or trucks when the vehicles are subjected to sudden starts or stops. The magnitude of impact shocks are varied by the use of different release points along the incline. FED-STD-101, Method 211, specifies testing procedures for packs subjected to this test.

17-2.8.4 Revolving Drum Test

This test involves the use of a hexagonally shaped revolving drum 7 or 14 ft in diameter. The item being tested is inserted into the drum and allowed to tumble and slide. Any weakness of the item can be determined due to this simulated rough handling test. It may also be used as a comparison of containers and alternate containers or for comparing banded versus unbanded containers.

17-2.8.5 Drop Test (Free-fall)

The free-fall drop test should allow a free, unobstructed fall of the container at the orientation and direction desired. The lifting or holding device must not damage or weaken the container and a level steel or cement surface will be provided to absorb all shock without displacement. Weight, size, level of pack, and kind of container shall determine the height from which the item is dropped. Test Method 216 of FED-STD-101 must be consulted for proper procedure.

The drop test depicted in Fig. 17-8 is primarily used to simulate the fall of an item dropped by a man from a height he would normally use to lift and carry an item of that size. The container is dropped from a height of 30 in. systematically on all corners. In the event the container is a drum, barrel, or keg, the ends are marked off in quarters for application of the test to each section.

17-2.8.6 Edgewise Drop Test

The test as illustrated in Fig. 17-9 should be accomplished in accordance with Test Method 213, FED-STD-101. The container is supported on one edge at a height of 5 in. and the height at which the opposite edge of the container is allowed to fall freely, is as indicated in Table 17-2. The drop surface should be steel, concrete, or stone and of sufficient mass to absorb shock without deflection. The test is applied twice to opposite ends of the container. If the size of the container and the location of the center of gravity are such that the drop tests cannot be made from the prescribed height, the height of the drops should be the greatest obtainable.

17-2.8.7 Cornerwise Drop Test

Packs are tested in accordance with Test Method 214 of FED-STD-101. The pack is supported at one corner by a block 5 in. in height and another block at the other corner of the same side 12 in. in height. The lowest point is raised to a height as specified in Table 17-2 and

TABLE 17-2
GRADUATED DROP AND IMPACT TEST HEIGHTS

Gross weight of container and contents	Edgewise-drop test (2 drops each end)	Cornerwise-drop test (2 drops on each of 2 diagonally opposite corners of bottom)	Impact test (1 impact on each of 2 opposite ends) use either test	
lb	Height of drop, in.	Height of drop, in.	Pendulum drop, in.	Incline impact, ft
Through 250	30	30	14	7.0
Over 250 through 500	24	24	11	5.5
Over 500 through 1,000	18	18	8	4.0
Over 1,000	12	12	5	2.5

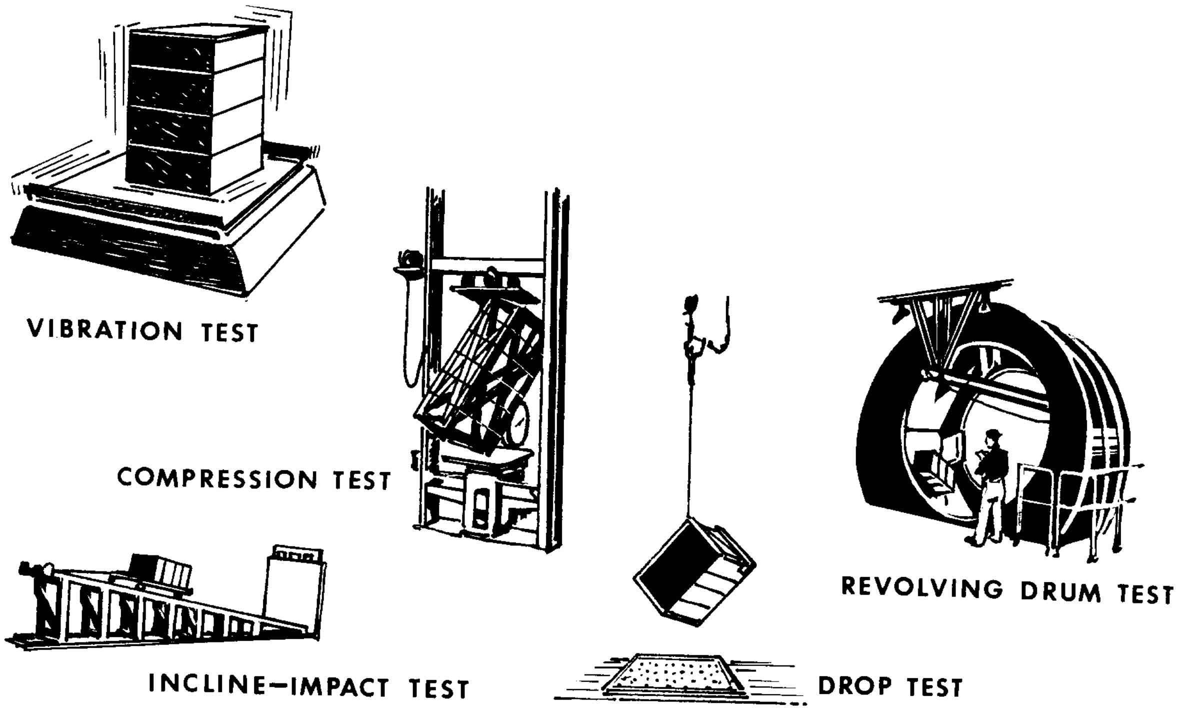


Fig. 17-7. Examples of Container Tests

then allowed to fall freely. The drop surface should be steel, concrete, or stone and of sufficient mass to absorb shock without deflection. The block positions are indicated in Fig. 17-10. If because of size or shape the test cannot be conducted properly, the edgewise test, as described in par. 17-2.8.6, may be substituted.

17-2.8.8 Pendulum Impact Test

The test as depicted in Fig. 17-11 is conducted in accordance with Test Method 212, FED-STD-101. The container is swung as a pendulum against a nominal 8 x 8 in. or larger timber resting horizontally on the floor, and securely blocked and fastened to prevent any movement. Table 17-2 indicates the height-weight ratio for this test. The opposite end also should be subjected to one impact. Specifications in relation to rigging and suspension may be found in Test Method 212, FED-STD-101.

17-2.9 DETERMINATION OF PRESERVATIVE RETENTION

Samples will be examined, where applicable, for retention of the preservative compounds. Evidence of failure of the item to retain compound, or evidence of corrosion–particularly at points of contact of the item with the barrier as shown in Fig. 17-12–will be cause for rejection (Refs. 2 and 5).

17-3 ENVIRONMENTAL CONTAINER TESTING (Ref. 3)

In addition to the tests of unit protection, containers may be exposed to laboratory simulated environmental extremes. Before any of these tests are specified, the logistic pattern of the packaged item should be studied, if possible, to be sure that an actual requirement exists. The value of some of the tests described may be questionable because, theoretically, a properly sealed container should require no additional information on the container's ability to protect its contents.

17-3.1 SALT SPRAY

This test requires exposure of the container to a spray of fog of concentrated saline solution for at least 48 hr. The test is intended to prove the ability of a container to withstand, and to protect its contents from, corrosive salt atmospheres. It is frequently used when there is some doubt as to the resistance of untried materials or finishes to corrosive salt atmospheres.

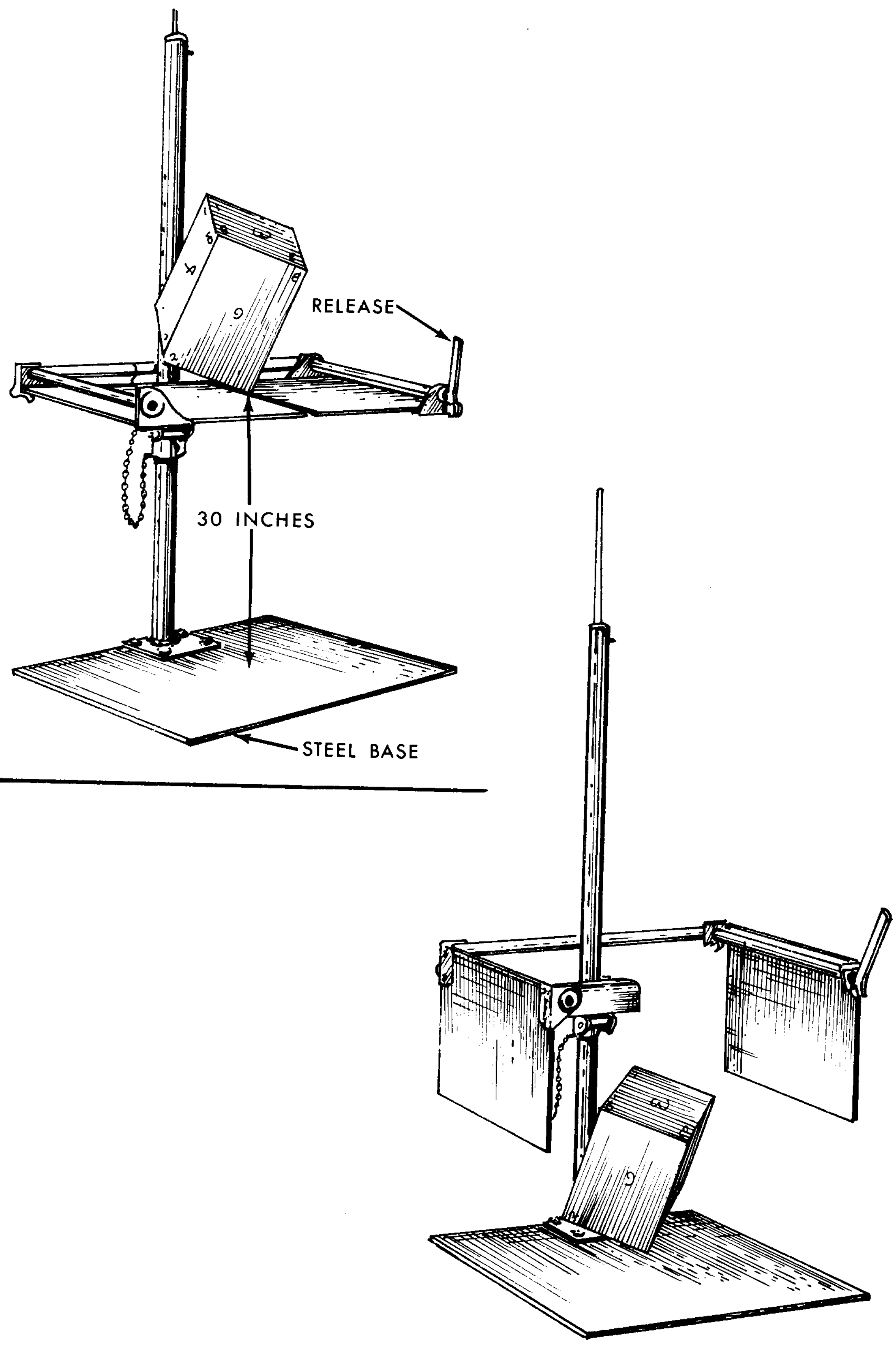


Fig. 17-8. Free-fall Drop Test

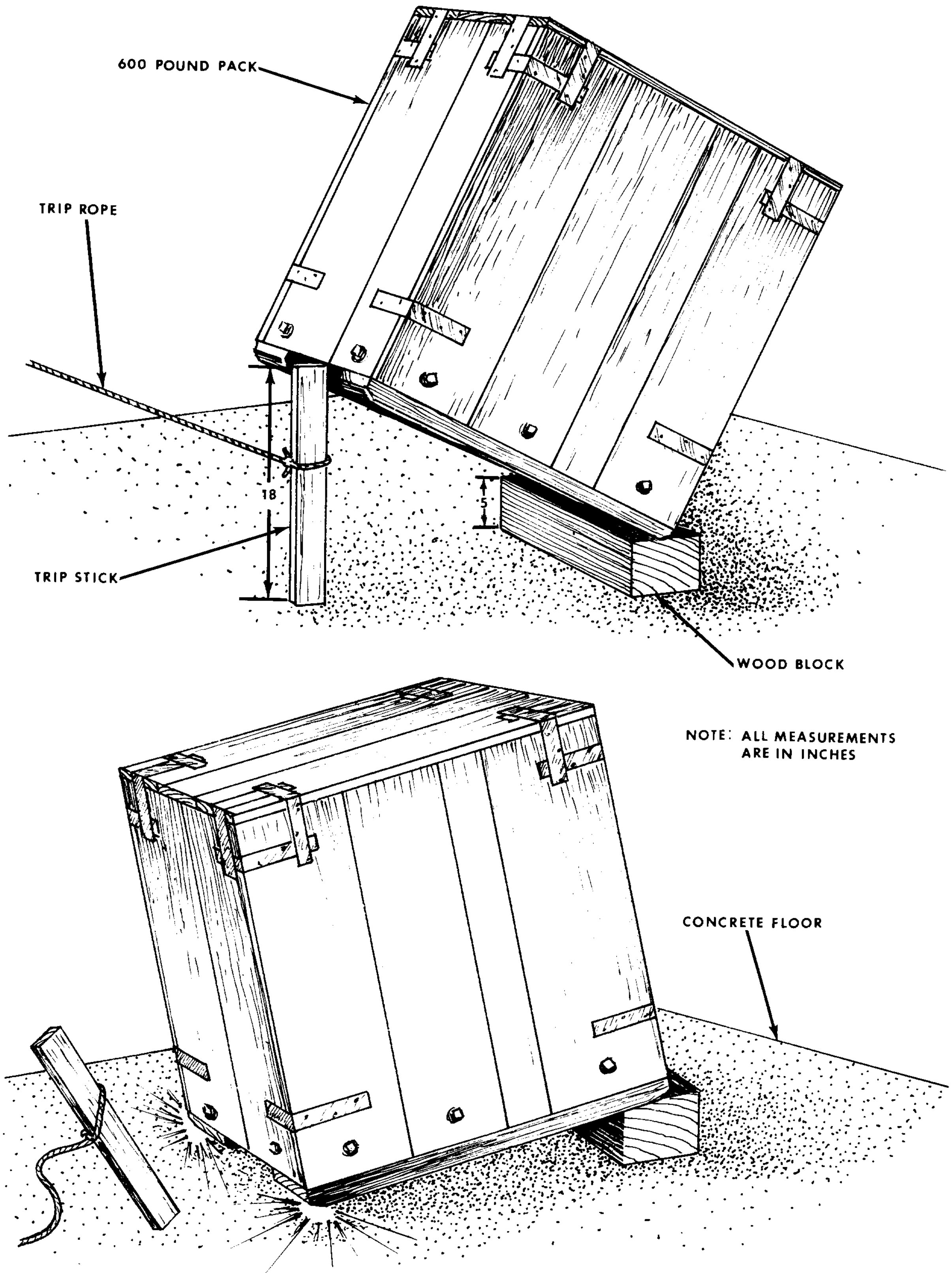


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Fig. 17-9. Edgewise Drop Test

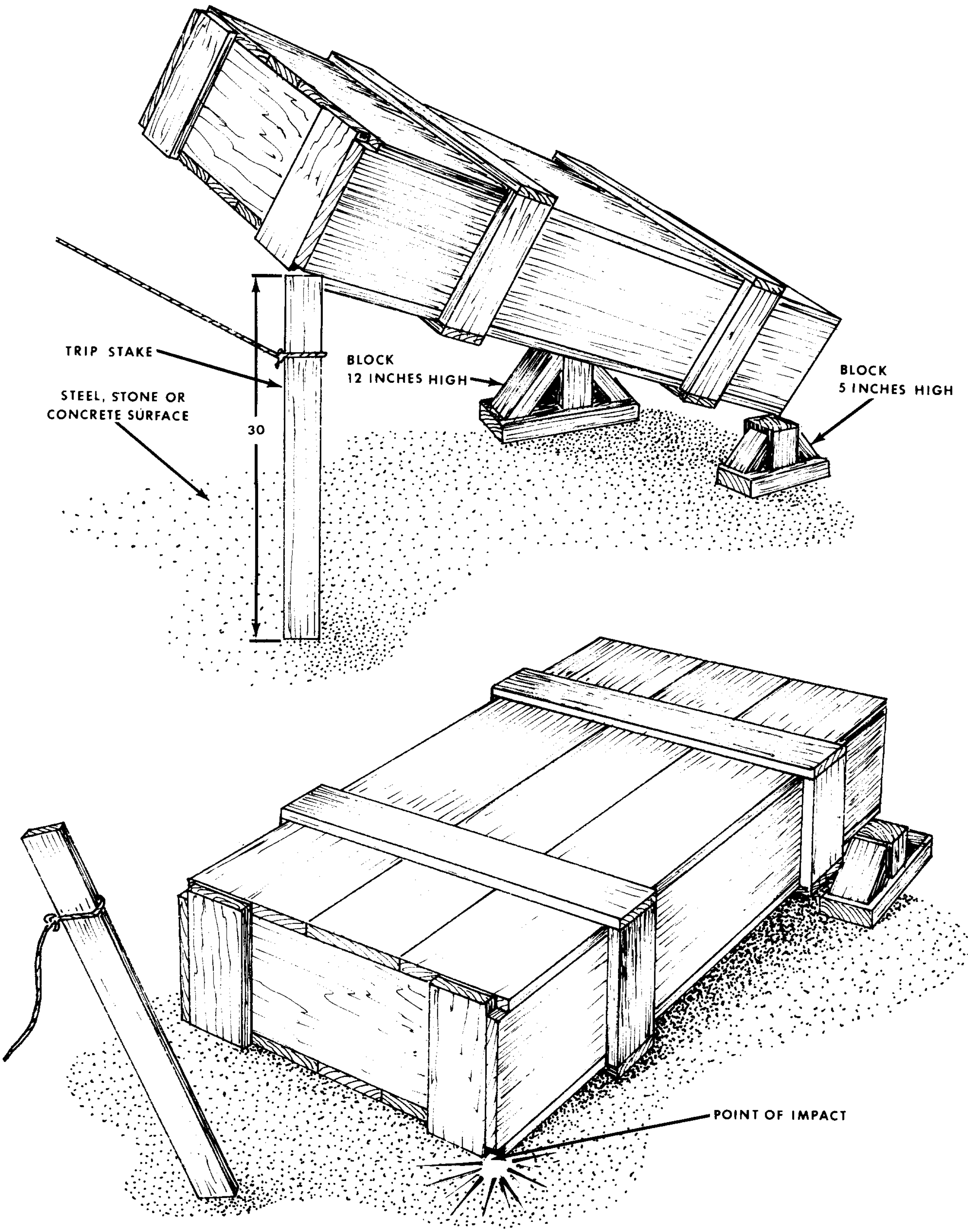


Fig. 17-10. Cornerwise Drop Test

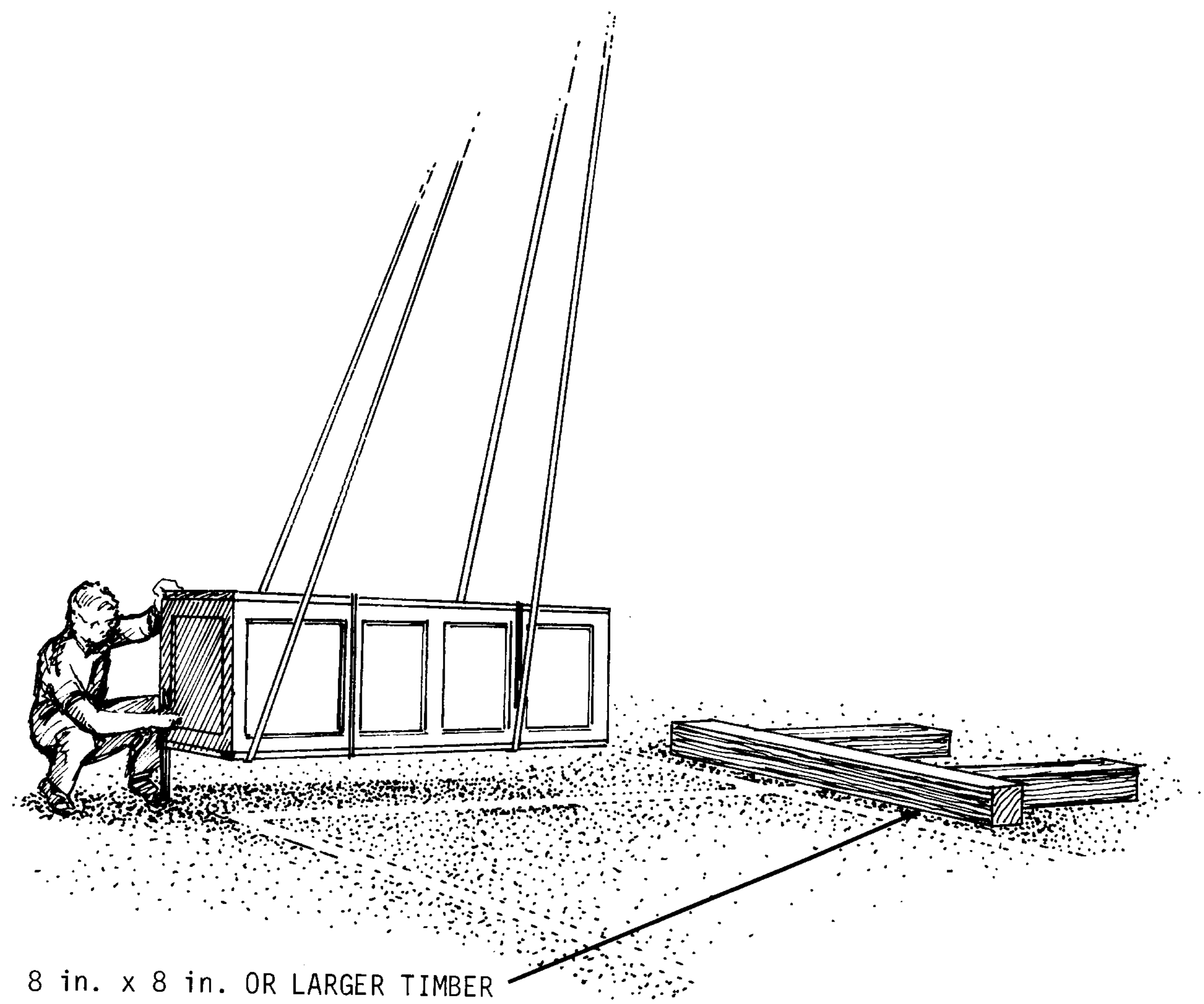


Fig. 17-11. Pendulum Impact Test

17-3.2 SAND AND DUST

In this test, the container is exposed to a mixture of sand and dust moving at velocities of 100 to 2500 ft per min, in a dry atmosphere. The purpose is to simulate sandstorm conditions. The test can be useful for unsealed containers with interior suspension systems or cushioning that may be damaged by sand and dust accumulations. The test can also be useful for sealed containers in evaluating exterior functional components and moving parts.

17-3.3 HUMIDITY

This test is designed to simulate the hot humid conditions of the tropics, but test conditions are more severe than those encountered in nature. The purpose of the test is to determine the ability of the materials, finishes, and components to resist deterioration and to function properly under extremely humid conditions.

17-3.4 RAIN

The purpose of this test is to determine the effectiveness of covers or cases used to shield the contents from the elements. The rain test is useful for covered, but unsealed, containers.

17-3.5 TEMPERATURE EXTREMES

High and low temperature tests are conducted to determine the effects of extreme temperatures on the

parts and operation of the container. It is frequently required that shock and vibration tests be conducted at the extreme operating temperature.

17-3.6 ALTITUDE

This test is primarily used to determine the ability of the container to withstand large, sometimes rapid, changes in differential pressure such as would develop during ascent or descent in unpressurized aircraft. An altitude test may also be used to determine the ability of a container to operate satisfactorily in mountainous regions where the atmospheric pressure is low.

17-3.7 FUNGI

The purpose of this test is to determine resistance to fungi that attack most organic and some inorganic substances. This test is unnecessary for complete containers because the resistance of most materials and finishes to fungi is already known. If new or untried materials or finishes are used, the test may be conducted on samples of the materials or finishes.

17-4 SIMULATED CONTENTS

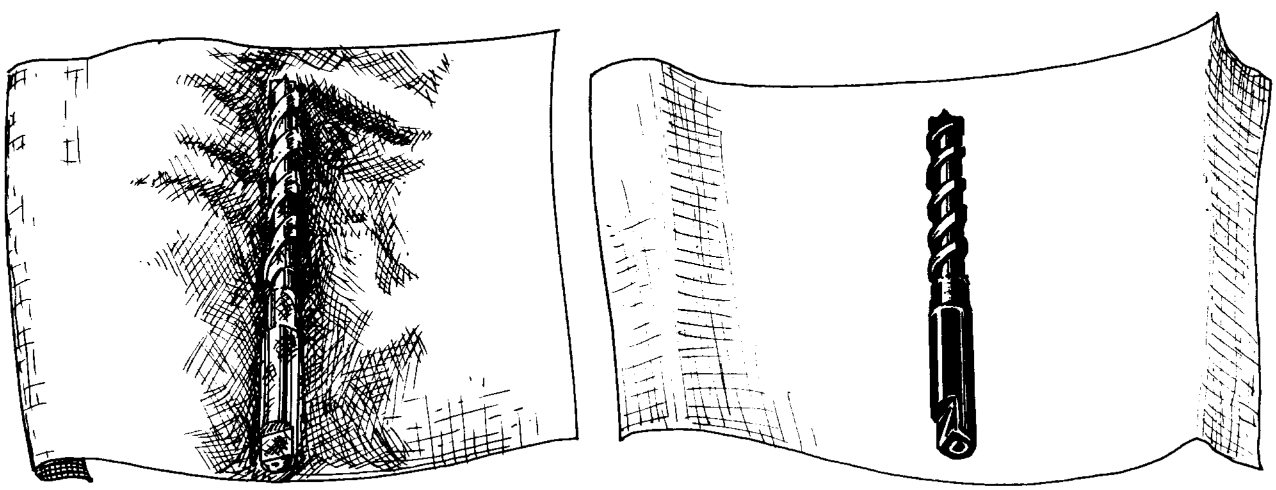
In order to avoid unnecessary damage or destruction of valuable commodities and to avoid possible hazards to personnel conducting the rough handling tests, simulated contents of the same dimensions, weight, and physical properties as the actual contents may, at the discretion of the procuring agency, be substituted in the tests. Also, a shock-recording instrument(s) of an acceptable type should be appropriately installed within the shipping container being tested.

17-5 DISPOSITION OF SAMPLES AFTER TEST AND INSPECTION

All samples used for inspection and tests will be reprocessed as necessary. They may, after reprocessing in accordance with the original method of preservation and packing, be considered a part of the original lot. When the packaged item may have been damaged as a result of testing, it will be inspected and if required, operationally checked, as necessary for determination of its serviceability. Test samples are selected at random in accordance with MIL-STD-105 (Ref. 6).

17-6 INTERPRETATION OF RESULTS

The previous paragraphs have briefly described a number of methods that have been devised for subjecting containers and packaging to hazards similar to those encountered in the field. Both laboratory and



PRESERVATIVE NOT RETAINED ON ITEM   PRESERVATIVE RETAINED ON ITEM

Fig. 17-12. Determination of Preservation Retention

field testing are necessary since there are certain conditions inherent in each method of testing that cannot be duplicated in the other.

Because containers in the storage and shipment cycle are subjected to various and constantly changing storage and shipping hazards, it is difficult to develop complete data for their design by merely observing the containers in service. Examinations of failures will reveal the weaknesses and suggest the specific principles of design to overcome such failures. However, laboratory tests are necessary to simulate field hazards since service tests are not performed under controlled conditions. Each test has been designed to reproduce one or more of the stresses and environmental hazards encountered in the field.

Evaluations of all test results will provide the data necessary to produce balanced packaging, construction, and workmanship. All materials and components which comprise the method of preservation and packaging must be free from damage or evidence of displacement, and there should be no evidence of failure on part of the item in retaining preservation compounds.

REFERENCES

1. TM 38-230-1, TM 38-230-2, *Preservation, Packaging, and Packing of Military Supplies and Equipment,* Vol. I and Vol. II.
2. NAVORD Report 6510, *Report on the Proper Method of Selecting and Specifying Preservation, Packaging, and Packing,* Bureau of Ordnance, Department of the Navy, October 1958.
3. U.S. Army Weapons Command, *Listing of Requirements for Missile Container Design,* Research and Engineering Division, Watervliet Arsenal, New York, 1962.
4. MIL-P-116, *Preservation, Methods of.*
5. FED-STD-101, *Preservation, Packaging, and Packing Materials, Test Procedures.*
6. MIL-STD-105, *Sampling Procedures and Tables for Inspection by Attributes.*
7. MIL-STD-810B, *Environmental Test Methods.*
8. MIL-STD-1186, *Cushioning, Anchoring, Bracing, Blocking, and Weatherproofing; with Appropriate Test Methods.*

CHAPTER 18

LIMITATIONS IMPOSED BY DISTRIBUTION SYSTEM

This chapter describes the limitations placed on a packaged item by the logistic and distribution pattern of the supply system through which the package moves. A listing of the Government and commercial agencies that regulate the shipment of the package is provided to aid the packaging engineer in meeting all the applicable regulations. The limitations imposed during the transportation, storage, and handling of the package as they govern the design of the overall package are discussed. The determination of the quantity per unit package and types of procurement as they affect the packaging engineer are also discussed.

18-1 LOGISTIC AND DISTRIBUTION REQUIREMENTS

The logistic flow for any one item is variable depending on the planned deployment of each individual item (Fig. 18-1). If the flow is known beforehand, the packaging engineer can often learn the type and length of storage, the type of handling equipment used, the rate and size of issue, and in some cases, the means of transportation. With this information available, significant economies can be made by eliminating requirements that are not applicable. Differences in the logistic patterns–such as destination, mode of transportation, etc.–can be used to advantage, though this idea does not mean that the packaging must always be different. Regardless of differences, there are certain constants that apply to all packages; the logistic flow only affects the design criteria.

The distribution pattern set up by the U.S. Army Materiel Command for the commodities it handles places further restrictions on the package. A possible distribution pattern for a typical ammunition item is shown in Fig. 18-2. The lack of knowledge of the distribution pattern for a particular item at the time of the package design is probably the major contributing factor in military packaging costs. If the package can be designed for a known distribution pattern, significant cost savings are possible. However, if the pattern changes and the protection of the packaged item is impaired as a result, these cost savings become worthless. The packaging engineer must design his package to prevent content damage and deterioration in the expected distribution pattern, yet not overpackage it, unless it is definitely established that the packaged item must be compatible to all known patterns.

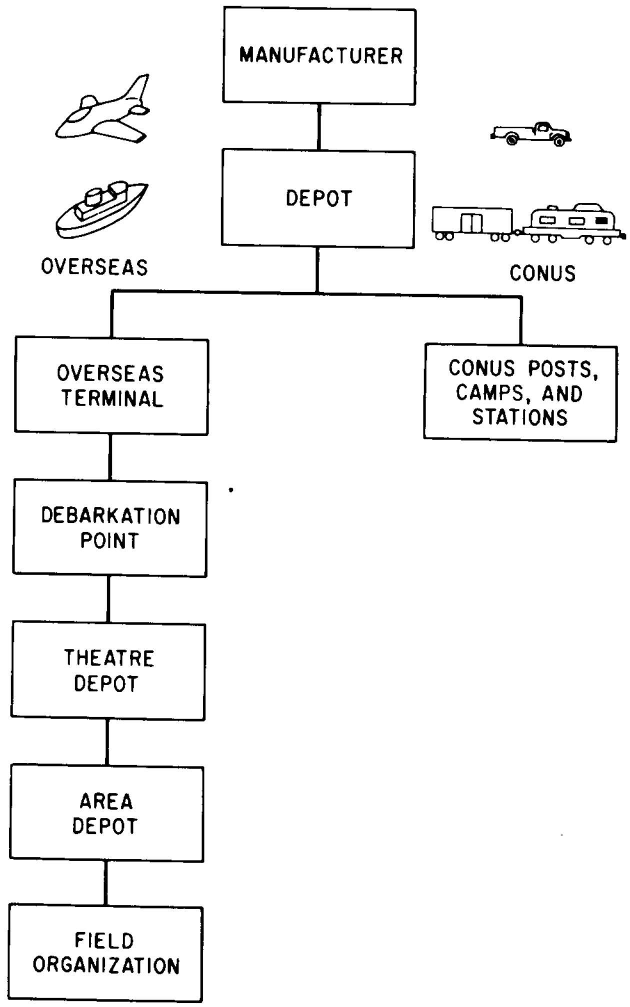


Fig. 18-1. Typical Logistic Flow

The most important consideration in the distribution, aside from the distribution pattern itself, is the determination of the quantity per unit pack. Under conditions of massive distribution, a superimposed package that carries the smallest quantity required by the ultimate user may be the best method of packaging. If the item moves through the system quickly and in small quantities, the unit package should be so designed as to stand on its own merits without the benefit of additional packaging. In the military system at the present time, the user normally orders and pays for only the required number of items without regard to the packaged quantity. Thus, the optimum package, which will meet all the logistic and distribution requirements, is the unit of use.

Although all items cannot be packaged in optimum quantities, this is an important consideration for the packaging engineer. The size of this package is intimately related to the packaging costs, and the shipping and storage space requirements. Often, the number of items that can be contained in an exterior container can be increased with little increase in weight by slightly reducing the size of the unit pack.

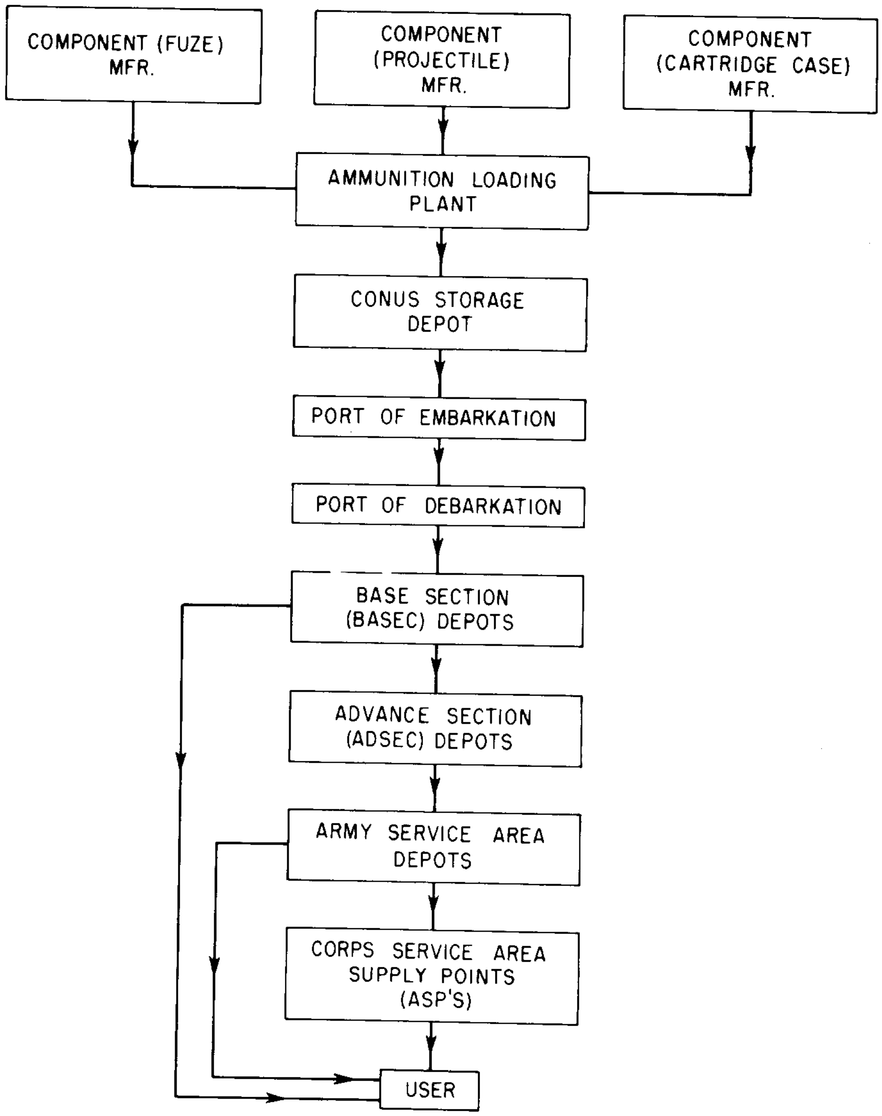


Fig. 18-2. Distribution Pattern for Typical Ammunition Item

18-2 REGULATING AGENCIES (Refs. 1, 2, and 3)

Regulations have been formulated by Government and commercial agencies to assure safety in handling, storage, and transit of packaged items and to reduce damage to a minimum. The established Government regulations may be found in appropriate Federal tariffs, such as the DOT regulations, and in related military regulations including DOD, Army, Navy, Air Force, Marine Corps, and Coast Guard Standards. The regulations of the commercial carriers may be found in the official publications of these agencies. The regulating agencies are covered separately in pars. 18-2.1 through 18-2.9.

In addition to the individual regulations prescribed by the various regulating agencies, separate regulations appropriate to all carriers have been established for explosive and dangerous materials. These regulations incorporate the specific regulations of the agencies concerned with the packaging, packing, transportation, and dispatch of dangerous materials. The following publications apply to the packaging, packing, marking, and transportation of dangerous and hazardous materials:

a. *Code of Federal Regulations, Title 49–Transportation, Parts 170 to 190,* 1968, U.S. Government Printing Office, Washington, D.C. 20402 (Also T.C. George's Tariff No. 19). DOT regulations for the preparation of explosives and other dangerous materials for transportation by rail freight, rail express, rail baggage, water and common, contract, or private carrier on public highways. Includes commodity list of articles, container specifications, packing instructions, marking requirements, billing and shipping forms, and required inspection procedures.

b. *Code of Federal Regulations, Title 14–Aeronautics and Space, Part 49–Transportation of Explosives and Other Dangerous Articles,* 1968, U.S. Government Printing Office, Washington, D.C. 20402. DOT regulations for transportation of explosives and other dangerous materials in all types of aircraft.

c. *Code of Federal Regulations, Title 46–Shipping, Part 146,* 1968, U.S. Government Printing Office, Washington, D.C. 20402. DOT regulations for transportation of explosives and other dangerous materials by water.

d. *CG 108, Rules and Regulations for Military Explosives and Hazardous Materials,* 1 May 1968. Regulations governing the transportation of military explosives as cargo on board all domestic and foreign vessels on the navigable waters of the United States, its territories and possessions, except for the Panama Canal Zone. Included are requirements for loading, unloading, storage, handling, packing, marking, and preparation of holds and compartments for dangerous materials.

e. *TM 38-250, Packaging and Handling of Dangerous Materials for Transportation by Military Aircraft,* 29 May 1968. Regulations covering the preparation, packing, marking, labeling, handling, and storing of explosives and other dangerous materials for shipment by military aircraft.

f. *Explosive Pamphlet No. 6,* Bureau of Explosives, Association of American Railroads, 2 Pennsylvania Plaza, N.Y., N.Y. 10001. Illustrates methods for loading and bracing carload and less than carload shipments of explosives and other dangerous materials to conform with DOT regulations for the transportation of explosives and other dangerous articles.

g. *Explosive Pamphlet No. 6A,* Bureau of Explosives, Association of American Railroads, 2 Pennsylvania Plaza, N.Y., N.Y. 10001. Illustrates methods for loading and bracing carload and less than carload shipments of loaded projectiles, bombs, etc. to conform with DOT regulations for the transportation of explosives and other dangerous articles.

h. *U.S. Postal Laws,* Post Office Dept. Publication 11, July 1968, Post Office Department, Washington, D.C. 20013. Contains regulations governing the shipment of explosive and radioactive material in the U.S. mails.

i. *Restricted Articles Regulations,* International Air Transport Association, 500 Fifth Avenue, N.Y., N.Y. 10036. Lists the conditions under which the various airlines will accept explosives and other dangerous materials for air transportation.

j. *Dangerous and Explosive Articles Tariffs,* National Classification Board, 1616 P Street, N.W., Washington, D.C. 20036. Contains applicable DOT regulations relating to the transportation of dangerous and explosive articles by motor freight.

18-2.1 DEPARTMENTS OF DEFENSE, ARMY, NAVY, AIR FORCE, AND THE MARINE CORPS

The Department of Defense and the Departments of the Air Force, the Navy including the Marine Corps, and the Army, regulate all items of military materiel and equipment during design, engineering, and construction so that the quantities of the final product

required for military use can be efficiently transported by available modes of transportation.

The policy and criteria of the Department of Defense with respect to the transportability of items of materiel are given in *Department of Defense Engineering for Transportability Program,* AR 705-8/NAVMATINST 4600.5/AFR 80-18/MCO 460.14, December 1964, Department of the Army, the Navy, and the Air Force, Washington, D.C. 20330. The regulations of the military relating to all phases of packaging are contained in Federal Specifications and Military Specifications and Standards. Federal Specifications are available from the Business Service Center, General Services Administration, Washington, D.C. 20405. Military Specifications and Standards–including Department of Defense, JAN, Army, Navy, and Air Force–are available at Army supply installations throughout the United States and from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120 or the Commander, Wright Air Development Center, Attention: WPAFB (EWBFSA), Wright-Patterson Air Force Base, Ohio 45433.

18-2.2 DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) regulates all common carriers engaged in transportation in interstate commerce and in foreign commerce that takes place within the United States. The DOT is authorized to promote safe, adequate, economical, and efficient service; to foster sound economic conditions in transportation and among the several carriers; and to encourage establishment and maintenance of reasonable charges for transportation services, without unjust discrimination, undue preferences or advantages, or unfair or destructive competitive practices. The DOT also acts as the liaison agency between states to ensure uniformity in state regulations. The DOT is concerned principally with developing, coordinating, and preserving a national transportation system by water, highway, rail, and other means that is adequate to meet the needs of the commerce of the United States.

The regulations of the DOT are contained both in Government and commerical publications. The title and contents of the Government publications are:

a. *Interstate Commerce Acts Annotated Supplements,* U.S. Government Printing Office, Washington, D.C. 20402. Contains a compilation of Federal laws relating to the regulations of carriers subject to the Interstate Commerce Act, with digests of pertinent decisions of the Federal Courts and the DOT, and the text of or reference to general rules and regulations.

b. *Code of Federal Regulations, Title 49–Transportation, Parts 0 to 70, 170 to 190, 91 to 164 and 165 to End,* 1968, U.S. Government Printing Office, Washington, D.C. 20402. Contains all the Federal laws relating to transportation including shipping, transportation, and storage regulations.

The regulations of the DOT may also be found in the following commercial publications:

a. *T.C. George's Tariffs,* Association of American Railroads, Transportation Building, Washington, D.C. 20006. An up-to-date version of the DOT regulations.

b. *Uniform Freight Classifications,* Uniform Classification Committee, 202 Union Station, Chicago, Illinois 60606. Contains a list of CL and ICL ratings, participating carriers and terminals, and sixty rules and regulations for packaging various commodities.

18-2.3 POST OFFICE DEPARTMENT

The Post Office Department regulates all postal material and its shipment including the admissibility, the collection, the processing, the dispatch, and the delivery of mail. The regulations of the Post Office Department are contained in both Government and numerous commercial publications. The titles and contents of the Government publications are:

a. *U.S. Postal Manual, Chapters 1 and 2,* Post Office Department, Washington, D.C. 20013. Explains the services available, and prescribes the rates, the fees and the conditions under which postal services are available to the public for domestic and international use.

b. *U.S. Domestic Postage Rates and Fees,* Post Office Dept. Publication 13, 1968, Post Office Department, Washington, D.C. 20013. Contains a compilation of domestic postal rates, fees, and charges for all postal services.

c. *U.S. Postal Laws,* Post Office Dept. Publication 11, July 1968, Post Office Department, Washington, D.C. 20013. Consists of a compilation of laws affecting the Post Office Department. Contains all of Title 39 of the *Code of Federal Regulations,* as well as pertinent parts of Titles 2, 5, 6, 7, 15, 16, 17, 18, 22, 26, 28, 31, 38, 40, 41, 45, 48, 49, and 50.

d. *Code of Federal Regulations, Title 39–Postal Service,* 1968, U.S. Government Printing Office, Washington, D.C. 20402. Contains a majority of the laws affecting postal service. See also pertinent parts of Titles 5, 6, 16, 18, 28, 31, 38, and 41 for additional information.

e. *Directory of International Mail,* Post Office Dept. Publication 42, 1968, Post Office Department, Washington, D.C. 20013. Contains detailed information about postage rates, services available, prohibitions, import restrictions, and other conditions governing mail to other countries. Countries are listed alphabetically, with the specific requirements applicable to the mail sent to each country.

The regulations of the Postal Department may also be found in *Leonard's Guide, Parcel Post and Express Freight* issued for each principal city in the United States. This guide contains information on domestic and international postal regulations along with an alphabetical index of parcel post zones by state and city or town.

18-2.4 UNITED STATES COAST GUARD

The functions of the Coast Guard embrace, in general terms, saving and protecting life and property; maritime law enforcement, providing navigational aids to maritime commerce and to trans-oceanic air commerce; promoting the efficiency and safety of the American Merchant Marine; and readiness for military operations. The Coast Guard is charged with the enforcement or assistance of enforcement of all applicable Federal laws upon the high seas and waters subject to the jurisdiction of the United States. The Coast Guard publishes regulations and educational pamphlets dealing with navigation, safety, and inspection of vessels. *CG 108, Rules and Regulations for Military Explosives and Hazardous Materials* covers hazardous material and is similar to *Code of Federal Regulations, Title 49, Transportation, Parts 170 to 190* and *T.C. George's Tariff No. 19.* The majority of Coast Guard regulations can be found in *Code of Federal Regulations, Title 46—Shipping,* Chapter 1, 1968, U.S. Government Printing Office, Washington, D.C. 20402.

18-2.5 RAILWAY EXPRESS AGENCY AND MOTOR FREIGHT CLASSIFICATIONS

The Railway Express Agency (REA Express) and motor freight lines are closely regulated by the Department of Transportation and to a lesser extent by other Government agencies. These transportation companies in turn also place restrictions on the material they will transport based on size, weight, and cost considerations. The rules and regulations of the REA Express are contained in the following documents:

a. *Official Express Classification No. 36 and Supplements,* Railway Express Agency, Inc., 219 E. 42nd St., N.Y., N.Y. 10017. Lists the class rating, rules, and regulations applying to express traffic covered by ICC Tariffs including Canadian traffic. The class rating of merchandise governs the express charge.

b. *Leonard's Guide, Parcel Post and Express Freight,* G.R. Leonard and Co., 79 Madison Avenue, N.Y., N.Y. 10002. Issued for each principal city in the United States. The guide contains information on REA Express and motor freight regulations along with an alphabetical index of express and rail freight zones by state and city or town. The guide also contains the applicable Canadian rules and regulations on motor express and rail freight.

18-2.6 AMERICAN TRUCKING ASSOCIATION

The National Freight Traffic Association Inc. publishes ratings, rules and regulations for the transportation of material by motor carrier. These requirements can be found in the *National Motor Freight Classification* and are in addition to the Government regulations. The Association guidance does not cover loading, blocking, or bracing of commodities for highway transportation. For this information, the applicable Military Specification should be consulted. The *National Motor Freight Classification* can be obtained from the National Classification Board, 1616 P Street, N.W., Washington, D.C. 20036.

18-2.7 ASSOCIATION OF AMERICAN RAILROADS

The Association of American Railroads establishes rules for transportation of materiel by rail. These rules can be found in the publications of the Freight Loading and Container Section and the Mechanics Division of the Association. An index of these publications can be obtained on request from the association headquarters, Transportation Building, 815 17 St. N.W., Washington, D.C. 20006.

18-2.8 CIVIL AERONAUTICS BOARD AND FEDERAL AVIATION AGENCY

The Civil Aeronautics Board (CAB) and the Federal Aviation Agency (FAA) regulate all phases of air commerce. The CAB is responsible for the economic regulations of air carriers, establishment and control of international civil aviation within the United States, and the promotion of safety in civil aviation. The FAA is responsible for originating safety regulations, the promotion of civil aviation through research and develop-

ment, the establishment and operation of air navigation facilities, air traffic management, and encouragement of civil aviation abroad.

The regulations of the CAB and the FAA are contained in both Government and numerous commercial publications. The titles and contents of these publications are as follows:

(1) *Code of Federal Regulations, Title 14–Aeronautics and Space,* 1968, U.S. Government Printing Office, Washington, D.C. 20402. Chapters I and III list FAA regulations, Chapter II contains CAB regulations, Chapter XV covers the restrictions of the Defense Air Transportation Administration, Department of Commerce.

(2) *Official Air Express Tariffs No. 1, 2, and 3,* Railway Express Agency, Inc., 219 E. 42nd Street., N.Y., N.Y. 10017. Lists the general and specific commodity rates and charges, and rules and regulations applying to air express traffic covered by CAB regulations. It includes an alphabetical index of air express zones by state, possession or province, and by city or town, which is used in conjunction with a table of rate scale numbers and a table of commodity rates and charges to obtain the total transportation charge.

(3) *Leonard's Guide, Parcel Post and Express Freight,* G.R. Leonard and Co., 79 Madison Avenue, N.Y., N.Y. 10002. Issued for each principal city in the United States. The guide contains the air express (REA) regulations along with a list of air freight forwarders and air freight lines.

18-2.9 FEDERAL MARITIME BOARD AND MARITIME ADMINISTRATION

The Federal Maritime Board is responsible for the regulation and control of rates, services, practices, agreements of common carriers by water including rates, fares, classifications, tariffs and practices, and shipping in foreign trade. The Federal Maritime Board also investigates discriminatory practices and subsidizes ship construction. The Maritime Administration is charged with the administration and execution of shipbuilding, shipping, port development, and other programs authorized by law. Many of its actions are based on decisions made by the Federal Maritime Board. The rules and regulations of the Federal Maritime Board and the Maritime Administration are contained in *Code of Federal Regulations, Title 46–Shipping,* Chapters II, III, and IV, 1968, U.S. Government Printing Office, Washington, D.C. 20402.

18-3 QUANTITY PER UNIT PACKAGE (Q/UP) (Ref. 4)

The quantity per unit package is established by the managing activity and is the smallest quantity issued. The unit of issue is usually first established by the cataloging personnel. This information then permits the packaging personnel to assign the quantity per unit package based upon this unit of issue. The assigned unit of issue established for a particular item name is based on considerations assigned in the following order:

(1) Common commercial practice

(2) Requirements of using personnel

(3) Usability in supply system.

The packaging engineer must take into consideration these basic requirements prior to any planning in the design of the unit package. Also, the following criteria must be considered in relation to the quantity per unit package.

a. Items assigned a unit of issue stated in terms of length or weight–such as foot, yard, ounce, etc.–are assigned a quantity per unit package of "bulk".

b. Items classified collection–type–such as kits, bags of hardware, and sets–are assigned a quantity per unit package of "1".

c. All other items are assigned a quantity per unit pack in accordance with overall supply effectiveness and economy taking into consideration the following, as applicable:

(1) Quantity per unit package prescribed in fully coordinated Military or Federal Specifications for the items

(2) Guidelines established by existing specifications for similar type items

(3) Chemical and physical characteristics including weight and size of item, construction and functional aspects, the fragility and critical or noncritical nature of the items

(4) Retail commercial practices for similar items

(5) Requirements for given items at the using echelon based upon available supply management data

(6) Mortality of the item(s)

(7) Quantities to afford ease of accountability and maintenance of items in the military supply system, including uniform quantities for inventory and storage

(8) Unit cost of item (excluding packaging cost) in accordance with the following formula:

Unit Cost	Q/UP
Up to and including 1.0 cent	100
Over 1.0 cent up to and including 10 cents	10
Over 10 cents	1

18-4 TRANSPORT LIMITATIONS (Ref. 4)

In a majority of cases, the packaging engineer must design the package without full knowledge of the conditions and forces to which the packaged item will be exposed while it is being transported. Military forces deployed throughout the world can be supplied by truck, railroad, ship, and aircraft. While in transit, the packaged item is handled many times between manufacturing facility, storage activity, and from one mode of transportation to another until it finally reaches the ultimate user. Modern equipment for handling supplies is still not available in many areas, and thus it is not uncommon to unload supplies by hand. Primitive forms of transportation–such as by animals, bicycles, and humans–are sometimes necessary in remote and inaccessible places. The packaging engineer must be concerned with all these limitations imposed by the transportation system to ensure that the packaged item reaches its destination safely. The limitations imposed on the package by the five main modes of transportation, trucks, railroads, ships, aircraft, and a combination of carriers, are described separately in pars. 18-4.1 through 18-4.5.

18-4.1 TRUCKS (Refs. 5, 6, 7)

Regulations restricting the size and weight of loads that can be legally transported on the highways in the United States are determined by the individual states. Although these limitations can be exceeded if permission is obtained, to do so causes a considerable increase in transit time and transportation cost, and requires special permits, special routing, police escorts, etc. The principal limitations imposed when shipping by highway arise from three sources:

(1) Limits imposed on size and weight of loads by various state governments

(2) Limits imposed on size and weight of loads by foreign governments

(3) Limits imposed by interior dimensions of military vehicles.

Because of the many different regulations, there is no one unitized group of restrictions that can be followed in each case. For the United States alone, there are fifty-one different jurisdictions, many of which change their regulations frequently. In addition, packages destined for overseas shipment must meet the regulations of the countries through which they pass.

18-4.1.1 Limits Imposed by State Governments

Most states now apply the recommendations made by the American Association of State Highway Officials, which allow the following limits: maximum gross weight, 73,280 lb; single-axle load, 18,000 lb; tandem-axle load, 32,000 lb; width, 96 in.; height 12.5 ft; and length of 50 ft for tractor-semitrailers and 60 ft for other combinations.

A summary of the highway size and weight limitations for the individual states and The District of Columbia (D.C.), is listed in Table 18-1. In many states, the maximum gross weight depends on a formula or a table in which the controlling factor is the wheelbase either of the individual vehicle or the overall length from the center of the first axle to the center of the last axle in the combination. In preparing Table 18-1, it has been assumed that the overhang, front and rear, totals 6 ft; i.e., approximately 3 ft from the front bumper to the center line of the front axle, and 3 ft from the center of the rear axle to the rear of the body or body bumper. Many trucks and trailers have a greater overhang than this, especially in the rear. Tandem-axle trailers used with two-axle tractors have considerable overhang, while five-axle tractor-semitrailers may readily come with the 6-ft overhang allowance. Gross weights shown in Table 18-1 are maximum values under the most favorable conditions. For vehicles of less than maximum wheelbase, it is necessary to compute the gross weight by formula or read it from the table. The laws of most states do not differentiate between front and rear axles in limiting maximum axle loads. It is, however, impractical to load the front axle beyond a certain point, which in the formula calculations for this table has been assumed to be 9,000 lb. For example, if the state allows 18,000 lb per axle, the practical gross load on a two-axle truck-tractor and single-axle semitrailer would be 9,000 lb front tractor axle, 18,000 lb rear tractor axle, and 18,000 lb on the trailer axle, or a total of 45,000 lb. In calculating the maximum gross for tandem-axle trailers, the calculations were based on three-axle tractors and tandem-axle trailers whenever the greater load allowed by this arrangement would be within the maximum gross allowable load. In calculating the total gross for tandem-axle trailers, it was assumed that the practical maximum length of a tractor-semitrailer is 50 ft. Thus, if the formula is $W = 750\ (L + 40)$, where L is distance between first and last axle, $L = 44$ ft

TABLE 18-1.
TRUCK AND TRAILER LIMITS BY STATES[5,6]

State	Height	Width	Length (B)				Axle Load Limits		Maximum* Gross Weight in Pounds			Formulas ** and Tables (.)
			Single Unit	Tractor Semi-Trailer	Truck Full Trailer	Tractor Semi & Full Trailer	Single, lb	Tandem 4' Apart, lb	Tractor & Semi-Trailer		Other Combinations	
									Single-Axle	Tandem		
Ala.	12'6"	96"	35'	50'T-5	N.P.	N.P.	18,000	36,000	45,000	64,650	N.P.	Table
Alaska	13'	96"	35'	60'	60'	60'	18,000 S-7	32,000	45,000 N	75,200	76,800	Table
Ariz.	13'6"	96"A	40'	65'	65'	65'	18,000	32,000	45,000	68,000	76,800	Table
Ark.	13'6"	96"	35'	50'T-5	50'	50'	18,000	32,000	45,000	56,000*** P	56,000 P	....
Calif.	13'6"	96"A-1	35'	60'T	60'U	65'D	18,000	32,000	45,000	68,000	76,800***	Table
Colo.	13'6"D	96"	35'	60'T-5	60'	60'	18,000	36,000	45,000	67,200***	75,200	Formulae (1)
Conn.	12'6"	102"	50'	50'T-5	N.P.	N.P.	22,400	36,000	50,000 Z-1	60,000	N.P.	....
Dela.	12'6"	96"	40'	50'	50'	60'	20,000 S-1	36,000	48,000	60,000	60,000	Table
D.C.	12'6"	96"	35'	50'T-5	50'	N.P.	22,000	38,000	56,400	63,890	65,400	Table
Fla.	12'6"	96"	40'	50'T-5	50'U-1	N.P.	20,000	40,000	49,000	66,450	66,450	Table
Ga.	13'6"	96"	39.55'	50'T-5	50'	N.P.	20,340	40,680	61,020 D	63,280 D	63,280	....
Hawaii	13'	108"	40'	55'	65'	65'	24,000	32,000	57,000	67,200	81,600	Formulae (2)
Idaho	14'	96"	35'	60'T-5	65'	65'	18,000 S-3	32,000	45,000	68,000***	76,800	Table
Ill.	13'6"	96"	42'	50'	50'	50'	18,000 S-3 D	32,000	45,000	72,000	72,000	....
Ind.	13'6"	96"	36'	50'T-5	50'	50'	18,000 S-3	32,000	45,000	72,000***	72,000	....
Iowa	13'6"	96"	35'	50'T-5	N.P.	N.P.	18,000 M-3	32,000 M-3	45,000 M-3	72,634	N.P.	Table
Kan.	13'6"	96"A	35'	50'T-5	50'	N.P.	18,000	32,000	45,000	63,890***	63,890	Table
Ky.	13'6"D	96"	35'	50'T-5 D	N.P.	N.P.	18,000 S-M-4	32,000 S M-4	42,000 S M-4	59,640 S-F	N.P.	....
La.	12'6"	96"	35'	50'T-5	60'	N.P.	18,000 S-6	32,000	36,000 P	64,000*** P	68,000 P	....
Maine	12'6"	96"	50'	50'T-5	50'	N.P.	22,000 S	32,000	50,000	60,000	60,000	Table
Md.	12'6"	96"	55'	55'T-5	55'	55'	22,400	40,000 I	53,800	65,000	65,000	Formulae (3)
Mass.	N.R.	96"	35'	50'T-5	45'U-2	N.P.	22,400 S-3	36,000	60,000	60,000	N.P.	Formulae (4)
Mich.	13'6"	96"	35'	55'T	55'	55'	18,000 S-1	26,000 J	45,000	68,000*** D	111,000 D	(3 Tables)
Minn.	13'6"	96"	40'	50'	50'	N.P.	18,000	32,000	45,000	72,500***	72,500	Table
Miss.	12'6"	96"	35'	50'T-5	50'	N.P.	18,000 S-4	32,000 D	45,000	55,650	59,000 D	Table
Mo.	13'6"Y	96"	35'	50'T-5	50'	50'	18,000 S	32,000	45,000	63,890***	64,650	Table
Mont.	13'6"	96"	35'	60'T-5	60'	60'Z-2	18,000	32,000	45,000	68,000***	76,800	Table
Neb.	13'6"	96"	40'	60'T-5	60'U-4	60'	18,000	32,000	45,000	67,333	71,146	Table
Nev.	N.R.	96"	N.R.	N.R.	N.R.	N.R.	18,000	32,000	45,000	68,000	76,800	Table
N.H.	13'6"	96"	35'	50'T-5	50'	50'	22,400 S	36,000	52,800	66,400	66,400	Table
N.J.	13'6"	96"	35'	50'T-5	50'	N.P.	22,400 S-3	32,000	52,400 G	60,000	60,000	....
N. Mex.	13'6"	96"A-2	40'	65'T-5	65'	65'	21,600 S	34,320	52,200	75,600***	86,400	Table
N.Y.	13'	96"	35'	50'T-5	50'U	N.P.	22,400 S-3	36,000	53,800	65,000	65,000	Formulae (5)
No. Car.	12'6"	96"	35'	50'T-5	50'U	N.P.	18,000 S-M2	36,000 M-2	46,200	62,000 M-4	62,000 M-4	....
No. Dak.	13'6"	96"	35'	60'T-5	60'	60'	18,000 S-2	32,000	45,000	62,000	73,280 C-Y	Formulae (6)
Ohio	13'6"	96"	35'	50'T	60'U	60'	19,000 S-5	24,000 W	47,000	72,000*** W	78,000 W	Formulae (7)
Okla.	13'6"	96"	35'	50'T-5	50'	N.P.	18,000 S-5	32,000	45,000	73,280***	73,280	Table
Oregon	13'6"Y-D	96"A-1	35'	60'T-6-D	60'U-4D	65'Y-D	18,000 S-2	32,000	45,000	68,000	76,000 L-D	Table
Penn.	12'6"	96"	35'	50'	50'	N.P.	22,400 S-3	36,000	50,000	60,000	62,000	....
R.I.	12'6"	102"	40'	50'	50'	N.P.	22,400	44,800	50,000	60,000 Z	88,000 E	....
So. Car.	12'6"	96"	40'	50'	50'U-1	N.P.	20,000 M-1	32,000 M-1	49,000 M-1	63,890 M-1	68,350 M-1	Table
So. Dak.	13'	96"	35'	50'T-5	60'	60'Y	18,000 S	32,000	45,000	72,110***	73,280	Table
Tenn.	12'6"	96"	35'	50'T-5	50'U-1	N.P.	18,000	32,000	45,000	61,580	61,580	Table
Texas	13'6"	96"	35'	50'T-5	50'	N.P.	18,000 S-5	32,000	45,000	58,420	72,000 #	Table
Utah	14'	96"	45'	60'	60'	65'Y	18,000	33,000	45,000	76,500 C	79,900	Table
Vt.	12'6"	96"	50'	50'T-5	50'	N.P.	N.S. S	N.S. S	50,000	60,000	60,000	....
Va.	12'6"	96"	35'	50'T-5	50'	N.P.	18,000 M-4	32,000 M-4	45,000 M-4	56,800 M-4	56,800 M-4	Table
Wash.	13'6"	96"	35'	60'T	60'	65'D	18,000 S-7	32,000	45,000	68,000*** L-2	72,000	Table
W. Va.	12'6"	96"	35'	50'	50'	N.P.	18,000	32,000	45,000	63,890	73,280 L-1	Table
Wisc.	13'6"	96"	35'	50'T-7	50'U	N.P.	19,500 X	32,000	48,000 X	73,000*** X-1	73,000 X-1	Table
Wyo.	13'6"	96"	40'	60'T-5	60'	60'	18,000	36,000	45,000	72,110***	73,950	Table

TABLE 18-1.
TRUCK AND TRAILER LIMITS BY STATES[5,6] (Cont.)

FOOTNOTES

(.) - Tables may be obtained from State Motor Vehicle Administrators.
* - Maximum Practical Gross (see third paragraph General Remarks).
** - Formulas, 1 - 800(L + 40); 2 - Group of Axles less than 18', 700(L + 40), Group of Axles more than 18', 800(L + 40); 3 - 850(L + 40); 4 - 1000(L + 25); 5 - 34,000 + (L x 850); 6 - 750(L + 40); 7 - 900(L + 42 2/9).
***- 3-axle tractor with tandem axle semitrailer.
A - 102" across tires; A1 - 100" across tires; A2 - 102" on disignated highways.
B - Semi-Trailer length controlled by single unit length except where footnote appears.
C - With Proper Equipment.
D - On designated highways.
E - 3-axle truck with 3-axle trailer.
F - No tolerance allowed.

G - Vehicles registered before March 1, 1950 exempt.
I - 36,000 lb. if axles spaced less than 48" apart.
J - On designated highways one tandem per combination permitted 32,000 lb.
L - Permit required for gross weight over 60,000 lb. ; L-1 Permit required over 63,840 lb. ; L-2 - 72,000 lb. with permit on main highways.
M-1 - Plus 10% tolerance.
M-2 - 1000 pounds tolerance on 1 axle; M-3 - Plus 3% Tolerance; M-4 - Plus 5% tolerance.
N - Maximum 47,000 lb.
N. P. - Not Permitted. (N. R. - No Restriction)
N. S. - Not Specified.
P - Plus weight on front axle.
S - Subject to 600 lb. per inch tire requirements; S-1: 700 lb. ; S-2: 550 lb. ; S-3: 800 lb. ; S-4: on tires 9:75 and larger; S-5: 650 lb. ; S-6: 450 lb. ; S-7: 500 lb.

T - Semi-Trailer limited to 40'; T-5: not restricted; T-6: Semi-Trailer 40' with permit. T-7 - Measured from rear of semi-trailer to rear of tractor.
U - Full trailers limited to 35'; U-1 35' unless 3 axle, then 40'; U-2: 33'; U-4: 40'
W - 31,500 with tandem axles spaced more than 4' apart.
X - Includes 1,500 lb. tolerance single axle; X-1 - Includes all tolerances.
Y - With permit.
Z - Not less than 10:00 x 20 tires; not less than 27' between extreme axles.
Z-1 - Subject to tire size requirement.
Z-2 - At discretion of Highway Commission, may be permitted.
\# - Effective Jan. 1, 1960.

(Courtesy of: Truck-Trailer Manufacturers Association, Inc.)

(50 ft minus 6-ft overhang) and, after substitution, $W = 750\ (44 + 40) = 63{,}000$ lb.

These regulations dealing with vehicle axle load and gross weight limitations can be summarized as follows:

a. Vehicle axle loads (subject to gross weight limitations) allowed in all states are 16,000 lb for axles spaced between 3.5 ft and 7.5 ft from the nearest adjacent axle, and 18,000 lb for axles spaced more than 7.5 ft from the nearest adjacent axle.

b. Vehicle gross weight limitations (subject to axle load limitations) are 36,000 lb if the distance from the extreme rear axles to the extreme front axles is 10 ft or less and an increase of 850 lb for each additional foot in excess of 10 ft but not exceeding 42,000 lb. The limit of 42,000 lb is due to the maximum acceptable value authorized in all states for tractor and tandem-axle semitrailers.

In addition to the restrictions on weight, the packaging engineer must also observe the limits placed on the transport vehicle dimensions. The packaging container should be designed to permit versatility of transport through any state without first having to obtain special permits, routing, etc. The maximum width and height for over-the-road equipment which will meet the general requirements of all states are shown in Fig. 18-3. Maximum lengths of vehicles authorized in all states range from 35 ft for single units, to 50 ft for tractor-semitrailer units. The floor height of trailers will usually vary from 4 ft 1 in. to 5 ft depending on the size of the tires used. For standard flat bed trailers, this leaves a usable stacking height ranging from 7 ft 6 in. to 8 ft 5 in., assuming a 12 ft 6 in. maximum road height limitation. However, depressed flat bed trailers, having a floor height of only 1.5 ft can be used for oversize items. Special permits are required in these cases. For material and equipment designed or modified to be transported in body trucks, the maximum dimensions are generally as follows: 6 ft 5 in. high, 7 ft wide, 22 ft long, and 11,200 lb in weight. Since truck and full trailer units are not allowed in certain states, this type of vehicle should only be considered in special cases.

18-4.1.2 Limits Imposed by Foreign Governments

If the package is destined for overseas transport, the restrictions placed on the package by foreign governments must also be observed. Foreign highway limitations are generally more restrictive than those found in the United States. The general requirements applicable to most countries that cannot be exceeded for the carrier and container are: 11 ft high, 8 ft wide, and 16,000 lb per axle load. For specific limitations imposed by each foreign government on highway transportation, contact the embassy of the applicable country.

18-4.1.3 Limits Imposed by Interior Dimensions of Military Vehicles

In addition to the restrictions imposed by governments on transport vehicles, the packaging engineer must also consider the interior dimensions of the military vehicles that may be used to transport the material. The dimensions of the standard military vehicles are contained in data sheets that are available at the U.S. Army Tank-Automotive Command, Warren, Michigan 48090.

18-4.2 RAILROADS (Refs. 5 and 7-11)

The principal limitations imposed on the package designer by railroads result from three causes:

(1) Limits imposed by dimensions of railroad cars

(2) Limits imposed by clearance dimensions of the right-of-way

(3) Limits imposed by the weight and distribution of the load.

18-4.2.1 Limits Imposed by Dimensions of Railroad Cars

The dimensions of railroad cars vary widely throughout each country of the world. The data which follows represents the average limits found in *The Official Railway Equipment Register,* The Railway and Equipment Publication Co., N.Y., N.Y. (Quarterly), which lists all of the cars used on the railroads of North America with their limiting dimensions. For additional details on the most common cars and for information on various specialty cars used on North American railroads, consult the *Car Builders' Cyclopedia,* 1957, Association of American Railroads, Simmons-Boardman, N.Y., N.Y. 20006. When the shipment must also travel in foreign countries, the more restrictive limitations of these countries must also be taken into consideration. Some typical examples of railway cars used on North American and foreign railroads are given in Table 18-2. For detail information on foreign railroad cars, consult the applicable consulate or embassy, or the railroad industry in each country.

The most frequently used railroad car on the railroads of North America is the closed car, in particular the Class X box car. The limiting dimensions of the majority of Class X box cars are shown in Fig. 18-4.

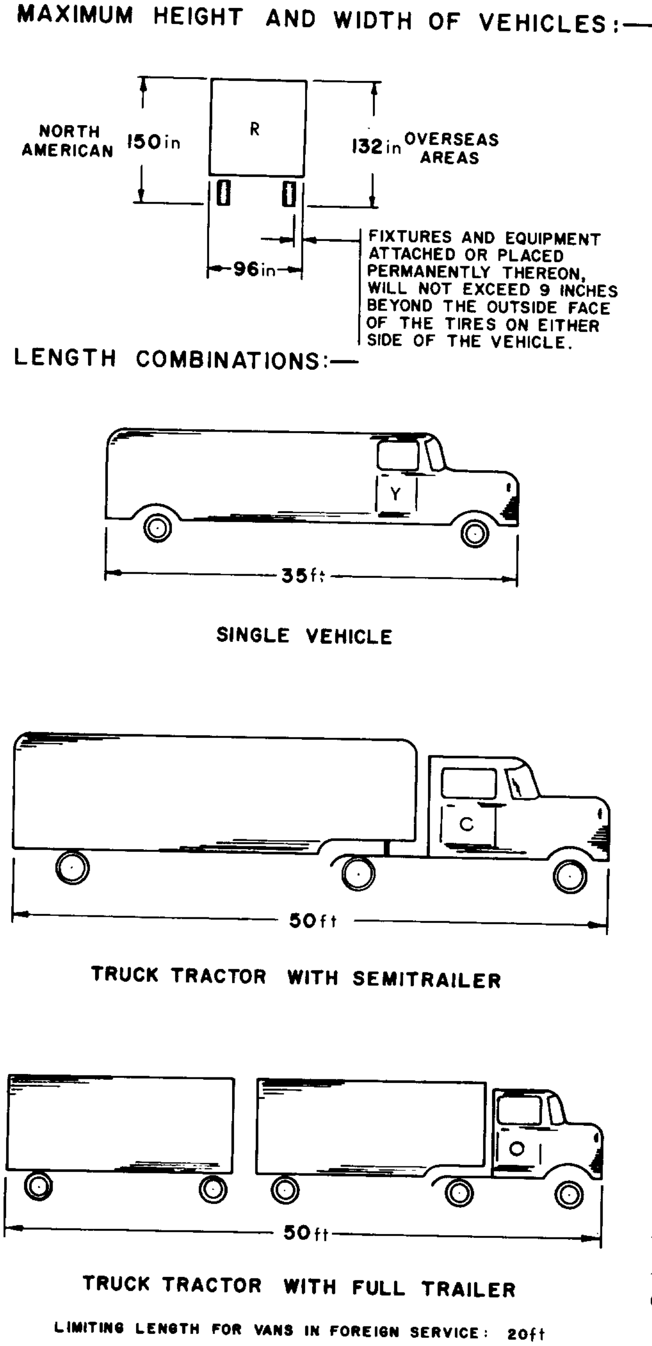


Fig. 18-3. Truck and Trailer Limits

Material too large to fit into the closed cars are carried on open cars–either a gondola car, a flat car, or a depressed-center flat car. Since flat cars and gondola cars are open, and the lading becomes, in effect, an extension of the car; the actual container limitations are imposed by the right-of-way clearance limits. The limiting dimensions of a majority of gondola cars are shown in Fig. 18-5. The limiting dimensions of a majority of flat cars are shown in Fig. 18-6. For depressed-center flat and well-hole cars, the well length is also a limiting dimension. In addition to the movement of oversize items, the gondola car can also be used for the bulk shipment of solids that may be exposed to the elements. However, hopper cars are more commonly used for bulk shipments since they are easier to unload. When the bulk material must be protected from the weather, closed hopper cars or box cars modified with partitions at the doors are used. For bulk shipments of liquids, tank cars having capacities from 40 to 70 tons are the most common means of transportation. Tank cars are available for practically any product that can be shipped in bulk.

18-4.2.2 Limits Imposed by Clearance Dimensions of the Right-of-way

To promote maximum efficiency of railroad transportation, railroad equipment and loaded rail cars should be within the clearance limitations of the right-of-way over which the load will travel. The types of physical barriers that impose right-of-way clearance limits are shown in Fig. 18-7. Since many of these limitations are dependent on bridges, tunnels, telephone poles, etc., they are subject to seasonal variations and to change as the railroad improves on its right-of-way. Where an individual shipment is very close to the published clearances, it is necessary to send a clearance car ahead of the train containing the shipment to ensure positively that the load will pass all obstructions. The use of the clearance car increases the transportation cost and time significantly. When a load exceeds the limitations, a special routing must be established for the shipment. The oversize load is placed in special trains, which move only at special hours at restricted speed, with careful control of meeting and passing traffic. This adds enormously to the transportation cost and time. For example, if it is considered normal for a transcontinental shipment to require three weeks, an oversize shipment may require as long as 12 weeks. Additional time is also required to obtain the special clearance routing of such shipments.

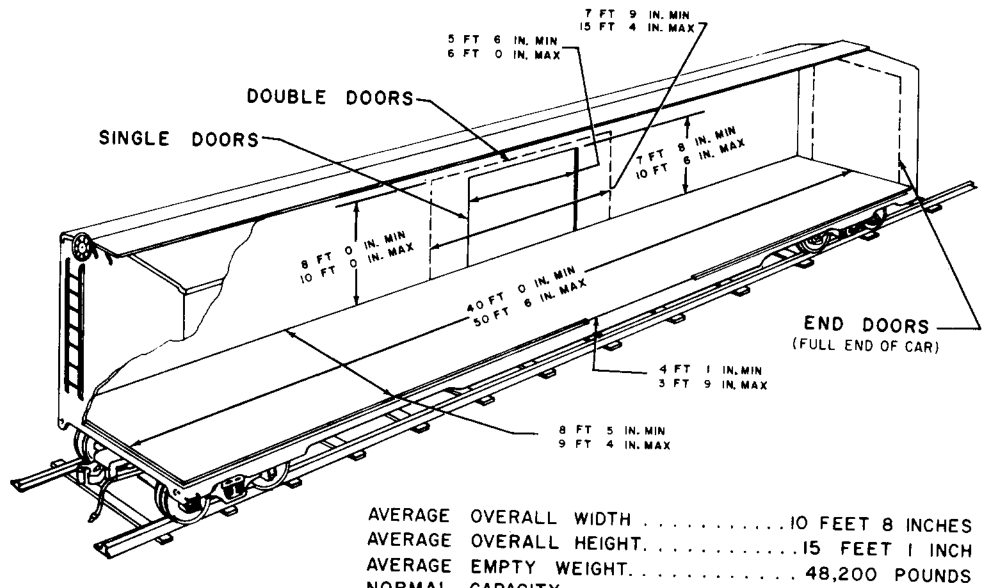
The standard railroad clearances for railroad transportation in North America and in Europe (Berne International) are shown in Figs. 18-8 and 18-9.

A more complete listing of clearances for Europe, North America, Central and South America, Africa, Asia, and Australasia is given in *World Railways 1961-62*, Sampson Lows, Publisher, London, England, 1962. The North American clearances are applicable to cars having the following dimensions: 50 ft, 6 in. inside length; 54 ft, 8.5 in. coupled length; and 41 ft, 3 in. between truck centers. If it is necessary to use cars exceeding these dimensions, a special study of clearance limitations must be made before shipment.

TABLE 18-2
DIMENSIONS OF COMMONLY USED RAILROAD CARS[8]

Type of Car	Nationality	Inside Length	Inside Width	Inside Height	Weight Capacity, lb	Side Door Width	Side Door Height
Open	N. American (flat)	41' 6" 42' 6" 45' 0" 49' 0" 50' 0" 52' 0" 52' 6" 53' 6"	* * * * * * * *	--	80, 000 140, 000	--	--
	N. American (gondola)	41' 6" 46' 0" 48' 6" 52' 6"	9' 6" 9' 6" 9' 1" 9' 5" 9' 6" 9' 6"	--	Up to 140, 000	--	--
	Turkey and Greece (flat)	60' 9" 49' 4"	8' 9" 8' 9"	--	70, 000 80, 000	--	--
	Turkey and Greece (gondola)	24' 7" 26' 9"	8' 10" 8' 10"	--	30, 000 30, 000	--	--
	Japan	18 - 42'	7-1/2 - 8-1/2'	--	N. A.	--	--
	Britain	17 - 20'	7-1/2 - 8-1/2'	--	N. A.	--	--
	France	20 - 25'	7-1/2 - 8-1/2'	--	N. A.	--	--
Closed	N. American	40' 6" 50' 6"	8' 6" 9' 2" 8' 6" 9' 2"	9' load height	75, 000 100, 000	8' 8" 10' and 15'	10'
	Turkey and Greece	24' 7" 32' 10"	8' 10" 8' 10"	N. A. N. A.	30, 000 31, 500	N. A. N. A.	6' 10"
	Japan	17 - 23'	7-1/2'	6-1/2 - 7-1/2'	N. A.	N. A.	N. A.
	Britain	17'	7-1/2'	6-1/2 - 7-1/2'	N. A.	5'	6'
	France	30'	7-1/2'	6-1/2 - 7-1/2'	N. A.	N. A.	N. A.

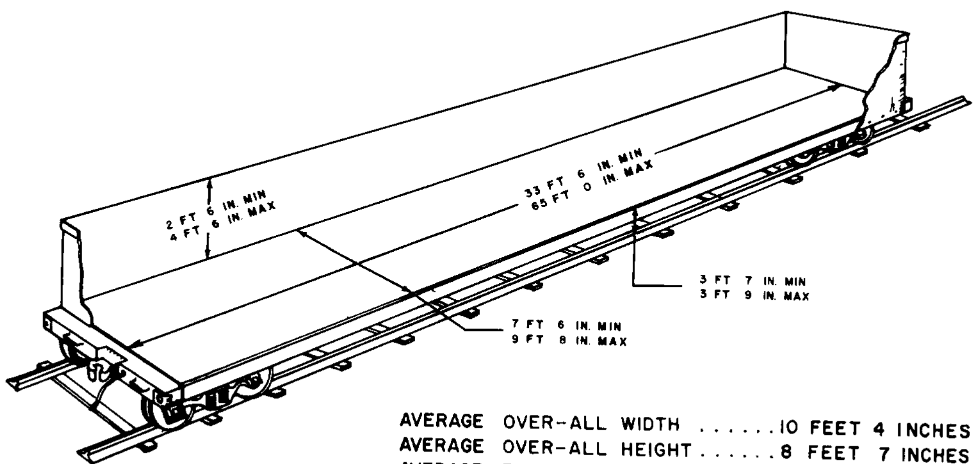
*Inside widths for each length listed are: 8'6", 9'2", 9'6", 10'2", and 10'6".
N.A. – Not applicable



AVERAGE OVERALL WIDTH . . . . 10 FEET 8 INCHES
AVERAGE OVERALL HEIGHT. . . . . 15 FEET 1 INCH
AVERAGE EMPTY WEIGHT. . . . . 48,200 POUNDS
NORMAL CAPACITY . . . . 40 TO 50 TONS

NOTE:
FOR OVERSIZE LOADS, CARS WITH REMOVABLE SIDES AND ENDS ARE AVAILABLE IN LIMITED QUANTITY.

Fig. 18-4. Closed Car Limitations



AVERAGE OVER-ALL WIDTH . . . . . . 10 FEET 4 INCHES
AVERAGE OVER-ALL HEIGHT . . . . . . 8 FEET 7 INCHES
AVERAGE EMPTY WEIGHT . . . . 42,800 POUNDS
NORMAL CAPACITY. . . . . 50 TO 70 TONS

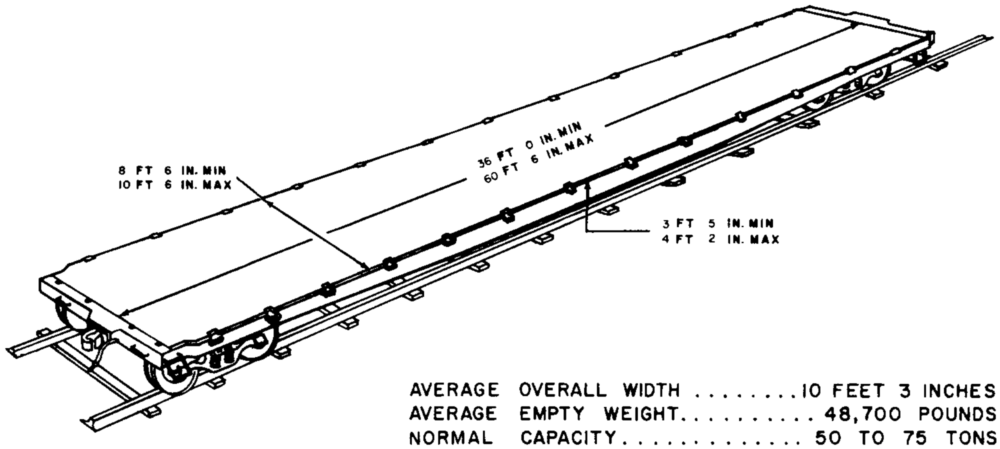
NOTE:
NO CLEARANCE REQUIRED FOR BLOCKING OR BRACING.
USE ANTI-CHAFING MATERIAL BETWEEN SIDES OF CONTAINER AND CAR WALL TO PREVENT CONTAINER DAMAGE.

Fig. 18-5. Gondola Car Limitations

Longer loads may be transported on open cars not exceeding these dimensions by overhanging the load on one car, or by utilizing idler cars. Loads transported by this method must conform to the criteria governing overhanging loads and use of idler cars published by the individual railroads. Containers up to 120 ft may be transported over conventional routes using this method if all other critical requirements are met.

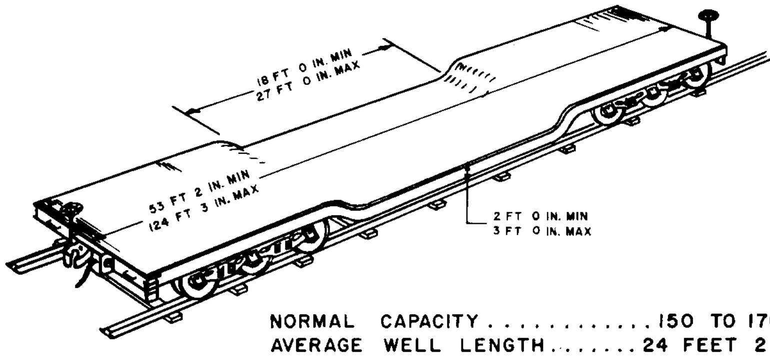
18-4.2.3 Limits Imposed by Weight and Distribution of Load

The total load that may be carried by a railway car is restricted by the weight limit of the car, and by the load limits of the rail bed, bridge, etc. over which the load will travel. When the load approaches the limits, the local freight agent should be consulted before ship-



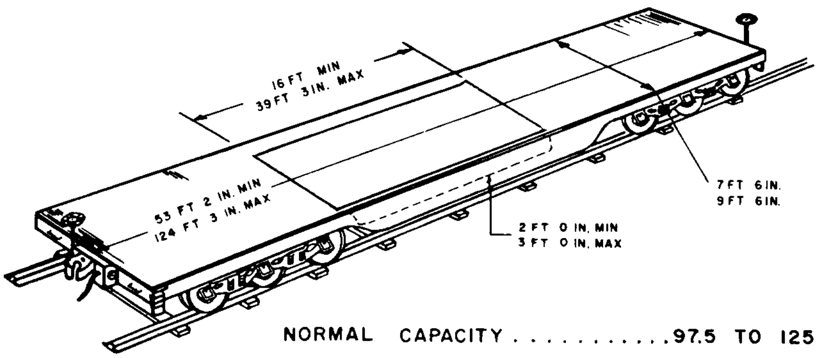
AVERAGE OVERALL WIDTH ....10 FEET 3 INCHES
AVERAGE EMPTY WEIGHT.......... 48,700 POUNDS
NORMAL CAPACITY............. 50 TO 75 TONS

(A) FLAT CAR



NORMAL CAPACITY............150 TO 170 TONS
AVERAGE WELL LENGTH........24 FEET 2 INCHES
AVERAGE WELL WIDTH.........8 FEET 6 INCHES
AVERAGE WELL HEIGHT........2 FEET 6 INCHES

(B) DEPRESSED-CENTER FLAT CAR



NORMAL CAPACITY...........97.5 TO 125 TONS

(C) WELL-HOLE CAR

Fig. 18-6. Flat Car Limitations

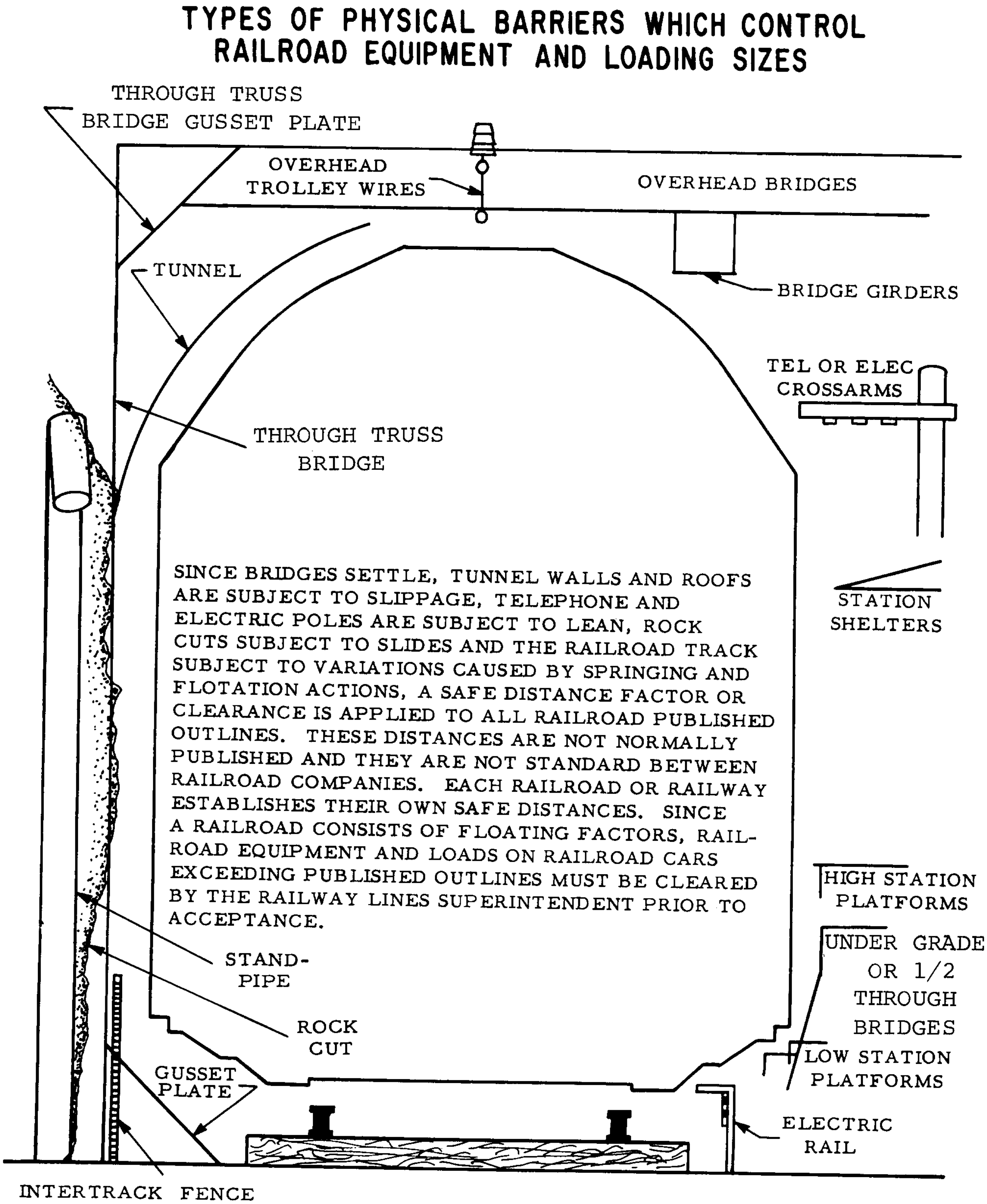


Fig. 18-7. Physical Barriers[5]

ment to ensure that the package can be efficiently carried.

In addition to observing the weight restrictions, the packaging engineer must ascertain that the weight is correctly distributed in accordance with Fig. 18-10. Lading which has oddly distributed loads must be carefully studied for stress and moment distribution, especially the dynamics of such loads on curves. Problems arising from oddly distributed loads may sometimes be resolved by shipping in a tilted or inverted position or by disassembling the item to be shipped.

18-4.3 SHIPS (Refs. 5 and 7)

Any container that can be transported to dockside can be handled and loaded on board ship. While special handling equipment can be made to load any given weight a ship can carry, the packaging engineer should limit the weight of individual containers to the boom capacity of the vessel to permit loading and unloading without the use of shore equipment. Since all cargo ships are equipped with at least a 5-long-ton (2,240 lb per long ton) boom, an 11,200 lb load can be loaded and unloaded anywhere by any type of vessel. If the container includes an explosive material, such as a complete missle with a high explosive warhead and a solid or liquid propellant motor, a Coast Guard weight limitation of 7,467 lb must be observed if the material is to be capable of being loaded and unloaded anywhere by any type of vessel. If two 5-long-ton booms are hooked in parallel, these weight limitations are doubled, but the placement of the load is then restricted by the reach of the two booms. For weight limitations of other types of explosives, preparation of the holds and compartments, and other stowage limitations when handling explosives, consult the references listed in par. 18-2.

The limitations of container dimensions imposed by each ship varies widely; however, for easy stowage aboard most vessels, the container dimensions should not exceed 35 ft in length, 20 ft in width, and 11 ft 4 in. in height. An optimum height of 6 ft 10.5 in. has been determined (Ref. 12). Dimensional data for three types of ships are shown in Figs. 18-11, 18-12, and 18-13. The length and width dimensions of containers for in-hold storage are limited by hatch size. Containers slightly longer than the hatch size can sometimes be stowed by slightly tipping the container, assuming the height of the container does not exceed the height of the hold or compartment in which it is to be placed. The height of the 'tween decks holds (weather or main deck to lower hold) ranges between 6 ft and 12 ft, while the height of the lower holds varies between 7 ft and 25 ft. Statistics and characteristics of merchant ships are given in Refs. 13 and 14.

Containers are not restricted to in-hold storage, but may also use on-deck stowage. While on-deck stowage removes the restrictions placed upon containers by hatch and hold sizes, other size limitations are placed upon the container depending upon the type and size of the vessel used; however, these restrictions are usually less severe than those for below deck storage. If on-deck stowage is used, the container is usually afforded little protection against the elements.

18-4.4 AIRCRAFT (Refs. 5, 7, 15-26)

All containers used for air transportation should be designed to be transportable in the maximum number of types of available aircraft. This will assure the maximum utilization of aircraft and lessen the possibility of shortage of a particular type. When designing containers for the required degree of air-transportability, careful consideration must be given to the limitations imposed by the characteristics of the aircraft involved. The most important of these characteristics are:

a. Useful load at maximum design gross weight

b. Size, location, and configuration of door openings

c. Size and configuration of cargo compartments including limiting factors that may prevent full utilization of available space

d. Design strength of fuselage, cargo compartment floor, and loading ramp

e. Number, location, and rated strength of tie-down fittings

f. Cargo restraint criteria

g. Aircraft weight and balance factors.

If the aircraft should require ramps, the angular approach to the fuselage opening limits the maximum length of package. As the weight of a heavy container is transferred to the aircraft, there is a change in the attitude of the aircraft, modifying the effective door size unless compensating loading equipment is used. The package must meet the requirements given in Refs. 15 and 21.

18-4.4.1 Commercial Aircraft

The packaging engineer must design the air transportable package to meet the requirements of regulating agencies of the Government, the freight handler and forwarder, and the airline. It must be determined in which aircraft configuration the material can be

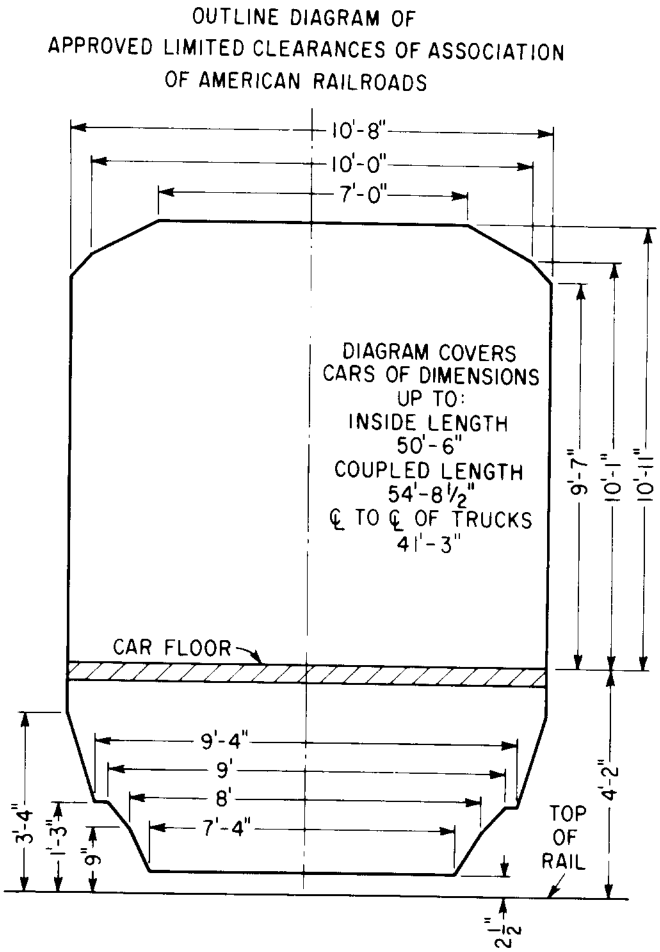


Fig. 18-8. Standard North American Railroad Clearances

transported–passenger, passenger-cargo, or cargo. It must also be determined whether the particular airline will carry the material. Some substances or items–depending on their contents, dimensions, weight, and ease of handling–are accepted by some airlines but not by others. Maximum package dimensions for several commonly used commercial aircraft are given in Tables 18-3 through 18-6. For information such as maximum floor loading capacity and cargo compartment weight limitations, consult, *Air Cargo,* a monthly publication, dealing with air freight, of American Aviation Publication, Washington, D.C. To use Table 18-4, find container height and width on vertical and horizontal scales of chart. Maximum allowable container length will then be found at intersection of the two scales.

18-4.4.2 Military Aircraft

Dimensional and ramp loading criteria for Army and Air Force aircraft are listed in Table 18-7. Refer to AMCP 706-130 (Ref. 15) for a more complete listing. Except for equipment items to be transported in Air Force aircraft, the Army CH-21, CH-34, UH-1B/D, or U1A aircraft, the outside dimensions of equipment items must be such as to permit loading and unloading with 6-in. vertical clearance after loading and 5-in. lateral clearance on each side during and after loading. The outside dimensions of equipment to be transported must be capable of being loaded and unloaded through side cargo doors to provide 1 in. vertical and lateral clearance at the doors and inside the cargo compartment during loading, and 6-in. vertical and 5-in. lateral clearance after loading. Consideration must also be given to clearance requirements for aisle space and access to controls and auxiliary equipment. For items that restrict passage through the aircraft, the transportation officer must be consulted for permission and guidance. Cargo compartment configurations for various military aircraft are shown in Figs. 18-14 through 18-20.

When the packaged item is to be transported by helicopter, depending on the dimensions of the package, either inside or outside loading can be used. When the packaged item is loaded inside the helicopter, the previously described aperture clearance limitations must be observed. If the load is to be transported outside the helicopter, the package suspension provisions must assure in-flight stability for the helicopter. Since many helicopters exhibit marginally stable characteristics, care should be taken to avoid aggravating this condition with the addition of an external sling load. It has been shown that the addition of a sling load can have an unfavorable influence on the dynamic stability. Instructions for rigging a typical sling load to assure its in-flight stability can be found in Ref. 15 and the applicable aircraft operating manual. The external load capacities of designated helicopters are listed in Table 18-8. The load capacities given are based on standard atmospheric conditions at sea level.

To assist the packaging engineer select the maximum payloads for air-transportability, sample payload distance graphs for selected Air Force aircraft are illustrated in Figs. 18-21 and 18-22; sample payload distance graphs for Army aircraft are listed in Table 18-9. For any payload, sufficient bearing area at the surface of contact between the container and the aircraft floor must be ensured to remain within the floor loading limitation. This limitation varies from approximately 0.3 psi (43 lb per sq ft) to 1,000 lb per sq ft, depending on the aircraft type. In addition to the other limitations, the restraint factors of the tie-down equipment must meet the requirements of the specific aircraft. Several

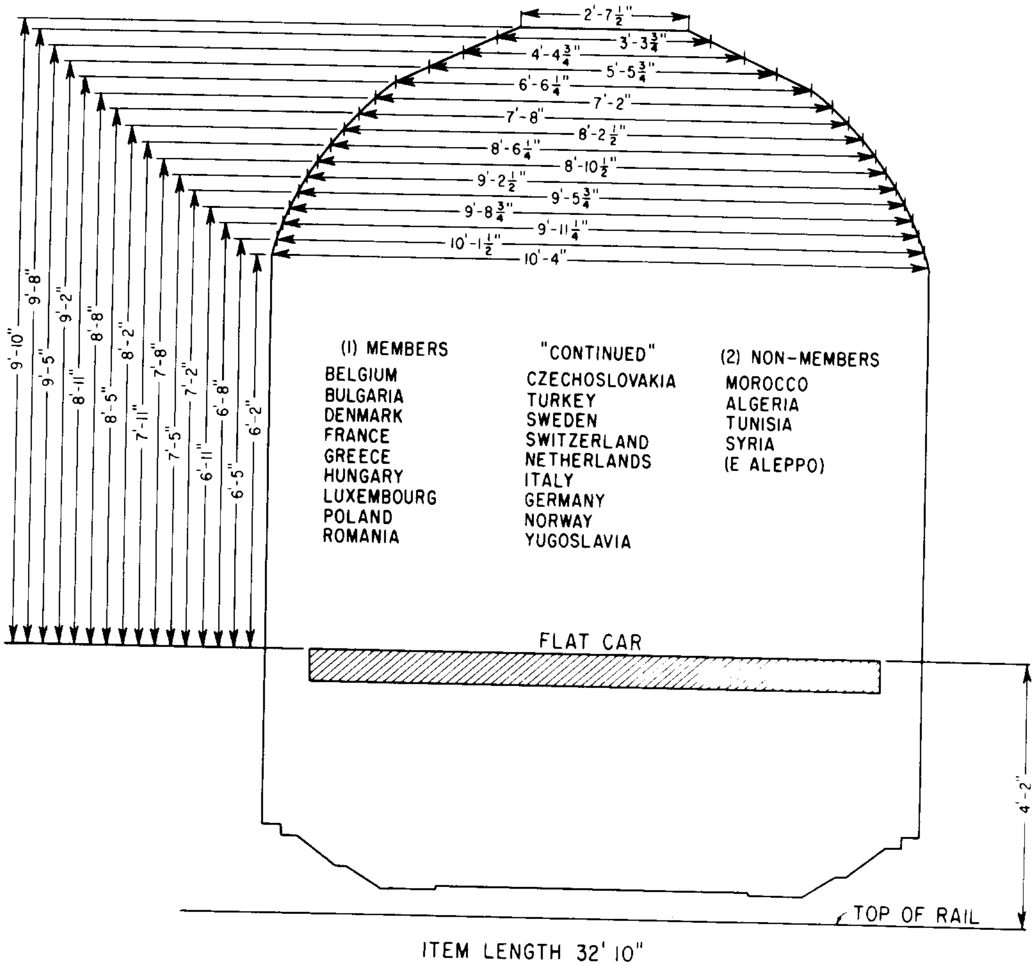


Fig. 18-9. Standard European Railroad Clearances, Berne International

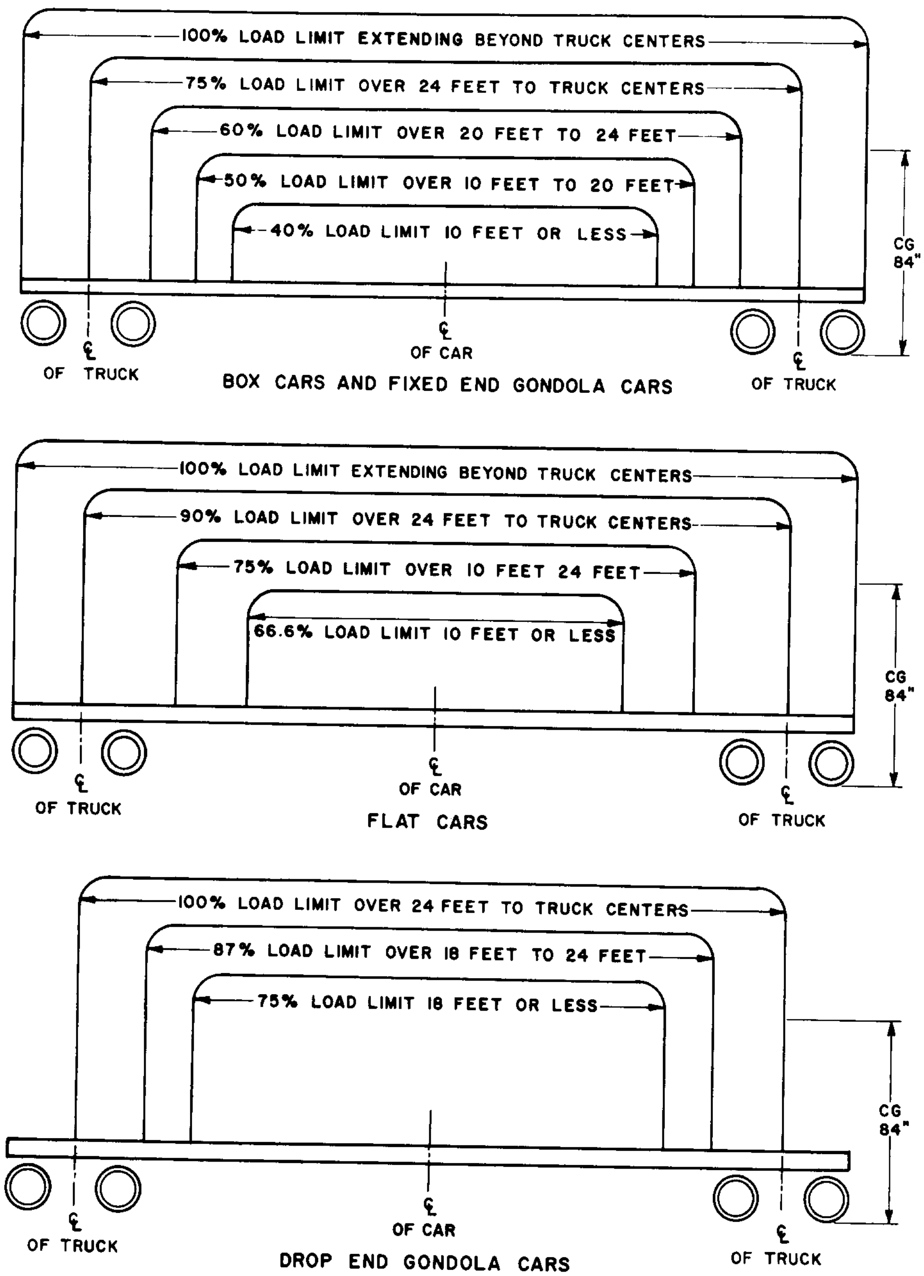
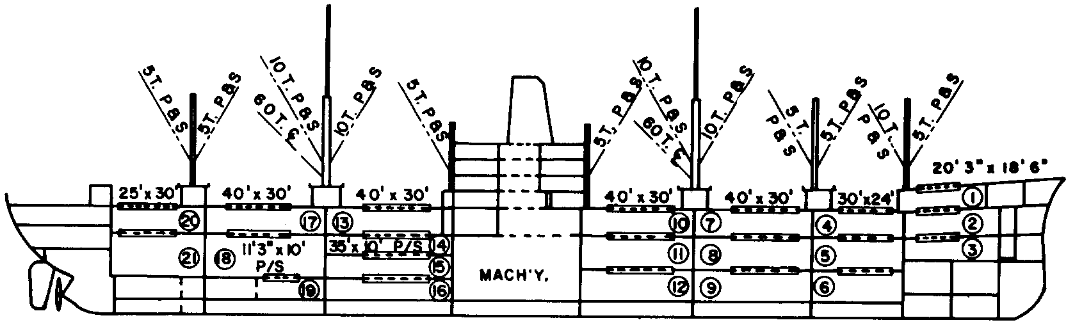


Fig. 18-10. Weight Distribution on Railway Cars[11]

MARITIME ADMINISTRATION DESIGN C4-5-Ia
MARINER CLASS



P-PORT LEFT SIDE S-STARBOARD RIGHT SIDE T-LONG TONS

COMPT NO.	CARGO BALE CU FT		CLEARANCE UNDER HATCH GIRDERS	COMPT NO.	CARGO BALE CU FT		CLEARANCE UNDER HATCH GIRDERS
	DRY	REFRIGER'D			DRY	REFRIGER'D	
1	16,085		7'-7"	13	41,775		8'-3"
2	18,140		10'-8"	14	16,388	16,256	7'-7"
3	12,210		11'-7"	15	16,022	13,998	7'-11"
TOTAL	46,435			16	38,135		10'-6"
4	29,255		9'-7"	TOTAL	112,320	30,254	
5	34,592		14'-3"	17	38,610		8'-2"
6	25,476		13'-10"	18	65,850		16'-10"
TOTAL	89,323			19	11,930		10'-6"
7	42,000		8'-9"	TOTAL	116,390		
8	58,150		12'-9"	20	25,095		7'-10"
9	51,375		13'-5"	21	34,220		18'-3"
TOTAL	151,525			TOTAL	59,315		
10	40,255		8'-4"				
11	60,020		12'-4"				
12	61,140		13'-5"	GRAND TOT.	736,723	30,254	
TOTAL	161,415						

Fig. 18-11. Ship Configuration (Mariner Class)[5]

examples are given in Table 18-10. The restraint criteria vary in accordance with aircraft characteristics. For information on location, capacity, and type of tie-down fittings, allowance for loading and unloading clearances, aisle space, and access to mechanical loading controls and auxiliary equipment, consult the applicable Air Force Technical Order or Army Technical Manual for the aircraft in question.

18-4.4.3 Air Delivery

Containers intended for air delivery must be designed to meet the limitations imposed by the air delivery system as well as those imposed by the aircraft in use. The most common methods of air delivery in use today consist of:

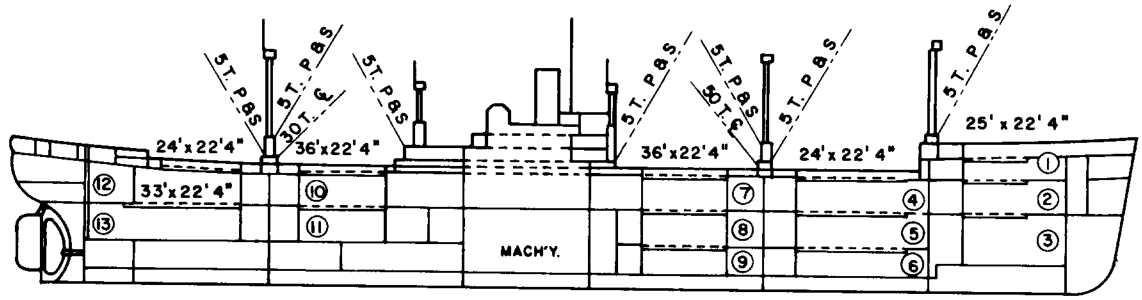
a. *Door Load.* The load is either pushed or skidded out of the aircraft door. The size and weight are dictated by the door size and capabilities of personnel to eject the load by hand.

b. *Wing Load.* The loads are containerized and attached to bomb racks under the wings of the aircraft. Load limitations are determined by the load-carrying capacity of the aircraft wings.

c. *Monorail.* The load is suspended from an overhead trolley and rail system allowing rapid dispersal of supplies and equipment automatically at evenly spaced intervals.

d. *Gravity.* The gravity method of air delivery consists of load-restraining ties released by a release parachute allowing the load to roll out of the cargo compartment of the aircraft which is flying at drop altitude in a slightly nose high attitude.

MARITIME ADMINISTRATION DESIGN VC2-S-AP3
VICTORY CLASS



P-PORT LEFT SIDE S-STARBOARD SIDE T-LONG TONS

COMPT NO.	CARGO BALE CUBIC FEET	CLEARANCE UNDER HATCH GIRDERS
1	18,730	6'-7"
2	23,785	9'-8"
3	27,910	15'-4"
TOTAL	70,425	
4	27,010	8'-5"
5	21,805	7'-7"
6	27,945	11'-4"
TOTAL	76,760	
7	45,555	8'-1"
8	37,795	7'-7"
9	52,840	11'-4"
TOTAL	136,190	
10	49,200	8'-0"
11	51,100	10'-4"
TOTAL	100,300	
12	43,630	10'-7"
13	25,905	10'-4"
TOTAL	69,535	
GRAND TOTAL	453,210	

Fig. 18-12. Ship Configuration (Victory Class)[5]

e. *Extraction.* The load is placed on a platform and extracted from the aircraft by the drag caused by deployment of a parachute. This method is particularly used in the delivery of large items such as vehicles, guns, or bulk supplies (Fig. 18-23).

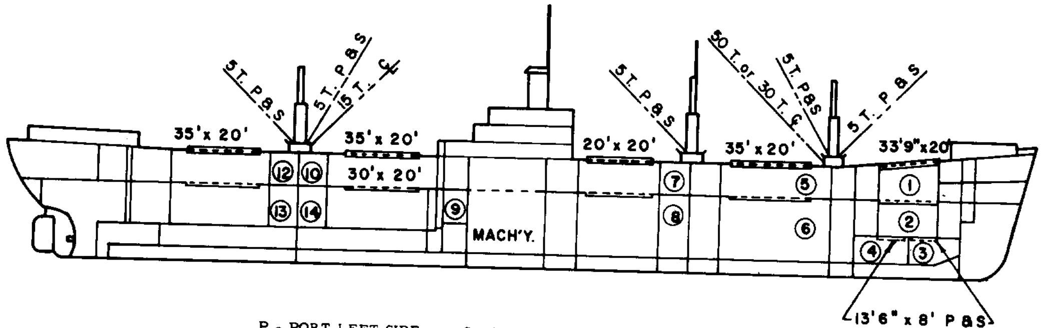
Air delivery systems consist of the following types now in use and are compatible with the methods of delivery previously mentioned:

a. *Skate Wheel and Buffer Board System.* The system consists of skate wheel roller conveyors and forward and side buffer boards to facilitate the movement of cargo as it leaves the aircraft (Fig. 18-24).

b. *Monorail System.* The system consists of 20 trolleys suspended from an overhead monorail, an electrically driven drum and cable, bundle guides, an anchor cable, and a trolley actuating system (Fig. 18-25).

c. *Dual-rail System.* The system is basically a system of roller conveyors with features for restraint and release of cargo. The loads are locked and released automatically by remote controls. The dual-rail system installation will vary due to aircraft type. However, the systems are functionally similar (Fig. 18-26).

MARITIME ADMINISTRATION DESIGN EC2-S-CI
LIBERTY CLASS



P - PORT LEFT SIDE S - STARBOARD RIGHT SIDE T - LONG TONS

COMPT No.	CARGO BALE CUBIC FEET	CLEARANCE UNDER HATCH GIRDER
1	39,322	12' - 1"
2	36,083	12' - 6"
3	5,733	7' - 10"
4	10,873	7' - 10"
TOTAL	92,011	
5	42,630	8' - 10"
6	92,008	22' - 6"
TOTAL	134,638	
7	23,904	7' - 10"
8	59,793	22' - 7"
TOTAL	83,697	
9	24,530	11' - 6"
10	29,689	7' - 10"
11	52,574	22' - 11"
TOTAL	106,793	
12	30,864	7' - 10"
13	51,571	24' - 7"
TOTAL	82,435	
GRAND TOTAL	499,574	

Fig. 18-13. Ship Configuration (Liberty Class)[5]

TABLE 18-3
MAXIMUM PACKAGE SIZE, MAIN CARGO DOOR, DC-8F AIRCRAFT[15]

HEIGHT, IN.	WIDTH, IN. 6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	128
	MAXIMUM LENGTH, IN.																				
6 to 48	1170	861	688	566	478	414	367	330	299	272	249	230	213	199	186	176	165	158	151	146	140
54	1128	830	660	547	463	403	359	323	293	266	245	226	210	196	184	174	164	157	149	144	
60	1012	738	600	503	433	383	342	308	280	257	237	220	206	192	181	171	162	154	147	140	
66	760	630	520	445	389	346	312	283	259	239	221	206	193	183	171	161	152	144			
72	629	518	441	385	340	305	278	253	233	216	202	189	178	167	157	148	140				
78	496	421	366	327	294	267	245	226	209	195	182	170	160	149	140						
84	369	325	291	263	239	219	202	188	174	161	148	136									

Note: This table does not reflect subcompartment apertures.

TABLE 18-4
CONTAINER SIZE LIMITS FOR C-54 AIRCRAFT[16]

DOUGLAS C-54

HEIGHT OR WIDTH, in. \ WIDTH OR HEIGHT, in.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54
2	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
4		550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
6			550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
8				550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	548
10					550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	544	541
12						550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	538	533	530	521	517
14							550	550	550	550	550	550	550	550	550	550	550	550	550	550	544	531	521	514	503	493	486
16								550	550	550	550	550	542	539	536	533	531	525	523	520	508	498	487	480	471	462	456
18									550	550	550	537	528	518	510	505	500	491	483	480	470	463	453	447	439	429	420
20										550	536	521	509	498	489	482	476	467	461	455	445	434	452	417	408	396	389
22											518	502	488	478	469	462	456	449	441	435	424	412	400	391	380	369	356
24												485	470	460	450	442	435	428	419	411	401	389	377	366	354	343	331
26													457	445	434	423	415	403	394	387	377	368	357	346	334	321	310
28														427	413	400	389	375	365	358	349	342	332	322	311	301	294
30															397	383	370	357	346	335	328	321	312	303	294	286	278
32																367	355	344	331	320	311	303	294	287	279	272	266
34																	342	330	317	306	296	287	280	273	266	260	254
36																		316	305	292	283	275	268	262	256	249	244
38																			293	280	272	265	258	252	245	238	232
40																				270	263	255	248	242	235	228	221
42																					255	247	239	232	226	219	211
44																						239	230	223	216	209	202
46																							222	214	207	200	192
48																								206	199	190	184
50																									191	183	176
52																										176	169
54																											163
56																											
58																											
60																											
62																											
64																											
65																											

HEIGHT OR WIDTH, in.	WIDTH OR HEIGHT, in.						WIDTH ONLY, in																				
	56	58	60	62	64	66	68	70	72	74	76	78	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
2	550	550	550	550	550	550	407	276	249	233	230	208	198	192	188	182	178	173	168	163	160	155	150	146	141	137	133
4	550	550	550	550	550	550	368	247	225	211	200	190	181	177	173	169	165	162	158	154	150	147	143	140	137	133	130
6	548	547	547	546	543	540	355	234	212	198	188	179	171	167	164	161	157	154	151	148	145	142	139	136	133	130	127
8	543	540	538	530	522	516	348	222	201	188	178	170	162	159	157	154	151	148	145	143	140	137	135	132	129	127	124
10	533	527	521	508	495	488	335	210	190	178	168	160	154	151	148	145	143	140	138	136	133	131	129	127	125	123	121
12	505	499	492	478	464	454	310	202	184	172	163	156	150	148	145	143	141	139	136	134	132	130	128	126	124	122	120
14	476	470	462	448	431	421	290	195	178	167	160	153	147	145	142	140	137	135	133	132	130	128	126	124	122	120	119
16	445	438	431	414	391	383	264	186	171	162	155	149	144	141	139	137	135	133	131	129	128	126	124	123	121	119	118
18	413	405	397	378	350	340	244	180	164	157	151	146	141	139	137	135	133	131	129	128	126	125	123	121	120	118	117
20	378	368	357	332	303	295	233	169	157	151	147	142	138	136	135	133	131	129	128	126	125	123	122	120	119	117	116
22	342	330	315	289	278	265	215	162	152	146	141	137	134	132	130	129	127	126	125	123	122	121	120	118	117	116	115
24	317	304	290	275	161	254	200	155	147	141	137	133	130	128	127	126	124	123	122	121	120	119	118	117	116	115	114
26	299	286	273	260	248	230	190	150	143	138	134	130	127	126	125	123	122	121	120	119	118	117	116	115	114	113	112
28	283	271	261	247	237	225	181	147	141	136	132	128	126	124	123	122	121	120	119	118	117	116	115	114	113	112	111
30	269	259	250	273	227	215	176	146	140	135	131	127	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110
32	257	247	238	227	218	208	172	144	138	133	129	126	123	122	120	119	118	117	116	115	115	114	113	112	111	110	109
34	246	237	228	218	209	199	167	143	136	131	127	124	121	119	118	117	116	115	114	113	113	112	111	110	110	109	108
36	235	226	217	209	200	191	160	141	135	130	126	122	119	118	117	116	115	114	113	112	111	111	110	109	108	108	107
38	225	216	208	201	192	182	156	139	133	128	124	121	118	117	115	114	113	112	111	111	110	109	108	107	107	106	105
40	214	207	199	192	184	175	153	138	132	127	123	120	117	116	114	113	112	111	110	110	109	108	107	106	106	105	104
42	205	198	191	184	176	168	150	137	131	126	122	119	116	115	113	112	111	110	109	108	108	107	106	105	104	103	102
44	195	189	183	176	169	160	146	136	130	125	121	118	115	114	112	111	110	109	108	107	106	105	104	103	102	101	100
46	186	180	175	168	162	156	142	134	128	124	121	117	114	113	112	110	109	108	106	105	104	103	102	101	101	100	99
48	177	172	167	161	155	149	139	132	127	123	119	116	112	111	110	109	108	106	105	104	103	102	101	101	100	99	99
50	170	164	159	153	157	143	136	131	126	122	118	115	112	111	110	108	107	106	105	104	103	102	101	100	100	99	98
52	163	158	153	147	143	137	132	127	123	120	116	113	111	110	108	107	106	105	104	103	102	101	101	100	99		
54	158	152	147	142	138	133	129	125	121	118	114	112	109	108	107	106	105	104	103	103	102	101	100				
56	152	147	142	138	134	131	126	122	119	115	112	110	108	107	106	105	104	103	102	102	101	100					
58		142	138	134	129	127	122	119	116	113	110	108	106	105	105	104	104	103	102	101	100						
60			134	130	125	123	119	116	113	111	109	107	105	104	103	102	101	100	99	99							
62				126	121	119	115	112	109	107	105	103	101	100	99	98	97	96	95								
64					117	114	110	107	105	102	100	98	96	95	94	93											
65						111	108	105	102	100	98	95	94	93													

FIND LENGTH (IN INCHES) AT INTERSECTION OF HEIGHT AND WIDTH

(Courtesy: Air Cargo)

Note: This table reflects main cargo aperture only.

In order to facilitate rigging procedures for the container to be air dropped, a number of air delivery platforms of various sizes have been developed. These platforms consist of three sizes of unstressed platforms (Standard B Platform)–11, 15, and 22 ft in length (Fig. 18-27); one stressed platform (J-1) 12 ft in length (Fig. 18-28); modular platforms of aluminum or wood (Figs. 18-29 and 18-30); and combat expendable platforms (Fig. 18-31). The Standard B Platforms are being replaced by combat-expendable platforms and will eventually become obsolete. Dimensions and weight limitations for combat expendable platforms are given in Table 18-11. These platforms can be used with the skate wheel and buffer board systems of air delivery.

For all types of platforms, deceleration and shock absorbing devices must be placed between the container and the platform to aid in the cushioning of the container when it lands. These devices should be designed for a maximum descent rate of 28.5 ft per sec.

The maximum load that can be placed on any standard platform is limited only by the strength of the aircraft floor. The minimum rigged weight required on most standard platforms is based on square footage of the platform. This weight is computed at 35 lb per ft^2 for combat-expendable platforms and modular platforms. The minimum rigged weight for loads using the 6,000-lb J-1 platform is 2,800 lb. The minimum rigged weights of loads placed on the 11-ft, 15-ft, and 22-ft Standard B platforms are 2570, 3740, and 6420 lb, respectively.

TABLE 18-5
MAXIMUM PACKAGE SIZE, MAIN CARGO DOOR, C-118/DC-6B AIRCRAFT[15]

WIDTH, IN.	HEIGHT, IN. 60 AND UNDER	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
	MAXIMUM LENGTH, IN.																		
3	623	623	623	623	623	623	623	623	620	612	598	570	547	521	499	473	446	428	412
6	623	623	623	623	623	623	623	620	605	593	[illegible]	542	521	501	476	499	431	418	393
9	623	623	623	623	623	623	623	618	595	579	554	523	494	477	453	438	417	394	382
12	602	601	580	575	560	545	530	511	504	496	472	458	432	417	404	387	372	363	354
15	550	534	519	506	498	489	475	460	445	436	420	403	392	380	369	358	349	341	330
18	484	477	463	452	444	435	424	414	406	398	384	373	361	349	341	330	321	312	302
21	430	421	414	409	401	395	385	376	367	358	350	339	328	321	313	304	298	289	282
24	398	390	385	379	368	363	359	348	339	330	326	322	319	308	299	291	284	279	271
27	365	358	350	347	341	336	329	322	315	307	298	289	281	278	272	269	266	263	259
30	336	330	328	324	319	311	304	300	294	286	279	271	264	260	257	254	251	247	245
33	318	311	307	301	298	292	287	282	278	271	263	255	248	244	239	235	231	227	224
36	290	286	284	282	280	276	272	267	263	256	249	243	235	231	228	224	219	216	213
39	274	271	269	267	264	260	256	251	248	242	237	230	224	219	215	211	205	201	198
42	259	256	254	252	250	247	243	238	235	230	225	219	214	210	204	199	196	193	189
45	247	244	242	240	238	235	231	226	223	218	213	208	204	201	197	193	189	185	181
48	234	232	230	228	226	223	218	214	211	208	204	199	196	192	188	185	181	177	175
51	222	220	218	216	214	210	207	203	200	195	191	188	184	180	177	174	172	170	168
54	210	208	206	205	202	198	195	193	191	188	185	181	179	173	171	168	165	163	162
57	198	196	194	192	190	187	185	183	182	178	175	173	171	167	164	162	159	157	155
60	189	186	184	182	180	178	176	174	173	171	170	169	168	163	160	158	155	153	149
63	181	179	177	175	173	170	168	166	165	163	160	158	156	154	151	149	146	144	142
66	174	171	169	167	165	164	162	160	159	156	154	152	151	148	146	144	142	140	138
69	169	166	163	161	160	159	158	154	152	150	148	147	146	144	141	139	137	135	134
72	163	161	158	156	153	151	150	148	146	145	143	142	141	139	137	136	134	132	130
75	157	155	152	150	147	145	144	142	140	139	138	137	135	134	132	130	128	126	
78	151	149	146	144	141	139	138	136	134	133	132	131	130	128	126	123	121	118	
81	146	143	140	138	135	133	131	130	129	128	127	126	125	122	120	116	115		
84	141	138	135	132	129	128	127	126	125	124	123	122	120	118	115				
87	136	133	130	127	124	122	121	119	118	117	115	114	113						
90	132	128	125	122	121	120	118	117	116	115	112								
93	127	124	122	119	116	115	114	113	112	111									
96	124	121	119	116	114	113	112												
99	120	118	116	114	112														
102	117	115																	
103	115																		

Note: This table does not reflect subcompartment apertures.

TABLE 18-6
CONTAINER SIZE LIMITS FOR 707 AIRCRAFT[16]

BOEING 707

First Dimension, in.

Second Dimension, in.		4	8	12	16	20	24	28	32	36	40	44	48
69	C	81											
68	A	108											
	A	126											
67	C	87											
65	C	94	81										
64	A	140	106										
63	C	102	89										
62	A	152	125										
61	C	110	97	81									
60	A	162	139	101									
59	C	120	106	90									
58	A	171	150	118									
56	A	181	160	130									
	C	133	118	104									
54	A	190	170	141	98								
53	C	146	131	118	95								
52	A	199	180	151	118								
50	A	208	188	160	130								
	D	175	152	138	135	118	97	88	82	54			
	C	159	144	132	117								
48	D	180	161	140	138	128	110	100	91	78	68	52	
47	A	221	201	174	147	121	106	94	84	63	53	---	---
	B	127	120	112	103	95	87	78	70	63	53	---	---
	C	171	156	144	132	118	107	100	70	62	52	---	---
44	A	232	214	186	161	137	123	113	105	96	85	65	---
	B	133	126	118	110	102	95	88	85	82	80	65	---
	C	182	167	156	144	130	119	110	82	80	80	64	---
	D	187	175	156	144	139	130	120	108	96	86	73	52
41	C	193	177	165	153	141	130	118	105	98	81	---	---
40	A	243	229	202	178	156	140	124	114	106	95	85	---
	B	149	141	134	133	130	124	116	109	102	95	85	---
	D	197	185	170	156	144	140	132	120	106	97	86	68
38	C	203	186	173	161	150	138	126	114	107	100	91	55
36	A	250	241	218	195	173	156	138	125	113	106	96	74
	B	169	168	162	153	145	136	128	120	113	106	96	74
	C	209	191	178	165	155	143	131	119	112	105	96	73
	D	209	192	182	166	155	146	141	131	117	106	96	78
33	C	218	200	185	171	160	148	137	126	120	112	103	84
32	A	255	250	233	210	187	168	149	135	125	114	105	87
	B	198	194	182	170	160	148	139	130	122	114	105	87
	D	221	202	192	173	162	150	148	140	131	120	108	91
30	C	226	207	191	177	165	153	142	132	126	118	109	92
28	A	259	257	243	225	200	179	159	149	138	124	113	96
	B	222	215	200	186	174	160	149	139	130	122	113	96
	D	232	211	198	180	167	155	150	148	141	132	120	100
27	C	234	214	197	182	169	157	146	137	131	123	114	98
24	A	263	261	254	238	212	189	179	168	156	140	123	103
	B	242	236	219	202	187	172	158	147	137	128	119	103
	C	241	220	202	187	173	160	149	141	135	128	119	103
	D	241	220	202	187	173	160	155	150	146	140	130	110
21	C	248	225	207	191	176	163	153	143	138	131	123	108
20	A	266	265	261	249	222	212	200	187	173	156	137	109
	B	261	257	238	218	200	183	167	153	143	133	125	109
	D	250	228	208	192	177	173	167	162	155	144	139	129
18	C	253	231	211	194	179	166	155	147	141	135	126	111
16	A	271	268	266	258	249	238	225	210	195	178	161	142
	B	269	268	256	233	213	193	175	159	148	138	129	114
	D	259	235	214	197	192	187	180	173	166	156	144	138
15	C	259	236	215	198	182	169	158	149	143	137	129	115
12	A	273	271	269	266	261	254	243	233	218	202	186	169
	B	272	270	269	248	224	202	181	164	152	141	132	118
	C	264	241	219	202	185	174	160	151	145	139	131	118
	D	264	241	219	214	208	202	198	192	182	170	156	140
9	C	268	246	223	205	188	176	163	153	147	140	132	120
8	A	274	272	271	268	265	261	257	250	241	229	214	197
	B	274	272	271	263	233	209	187	269	155	144	134	121
	D	270	247	241	235	228	220	211	202	192	185	175	161
6	C	272	250	227	208	191	177	165	155	148	141	133	122
4	A	276	274	273	271	266	263	259	255	250	243	232	216
	B	275	274	273	270	240	214	190	172	158	146	135	123
	D	274	270	264	259	250	241	232	221	209	197	187	180
3	C	275	254	230	211	194	179	167	157	149	142	134	123

A, B - TWA, PAA

C - AAL

D - CAL, BNF, WAL

A- Use when package weighs less than 50 kilos and may be turned on side for loading.

B - Use when package weighs 50 kilos or more or when it cannot be turned on side for loading.

Find Third Dimension (in inches) At Intersection Of First and Second Dimensions.

Courtesy: Air Cargo

TABLE 18-7
DIMENSIONAL CRITERIA FOR SELECTED ARMY AND AIR FORCE AIRCRAFT[15]

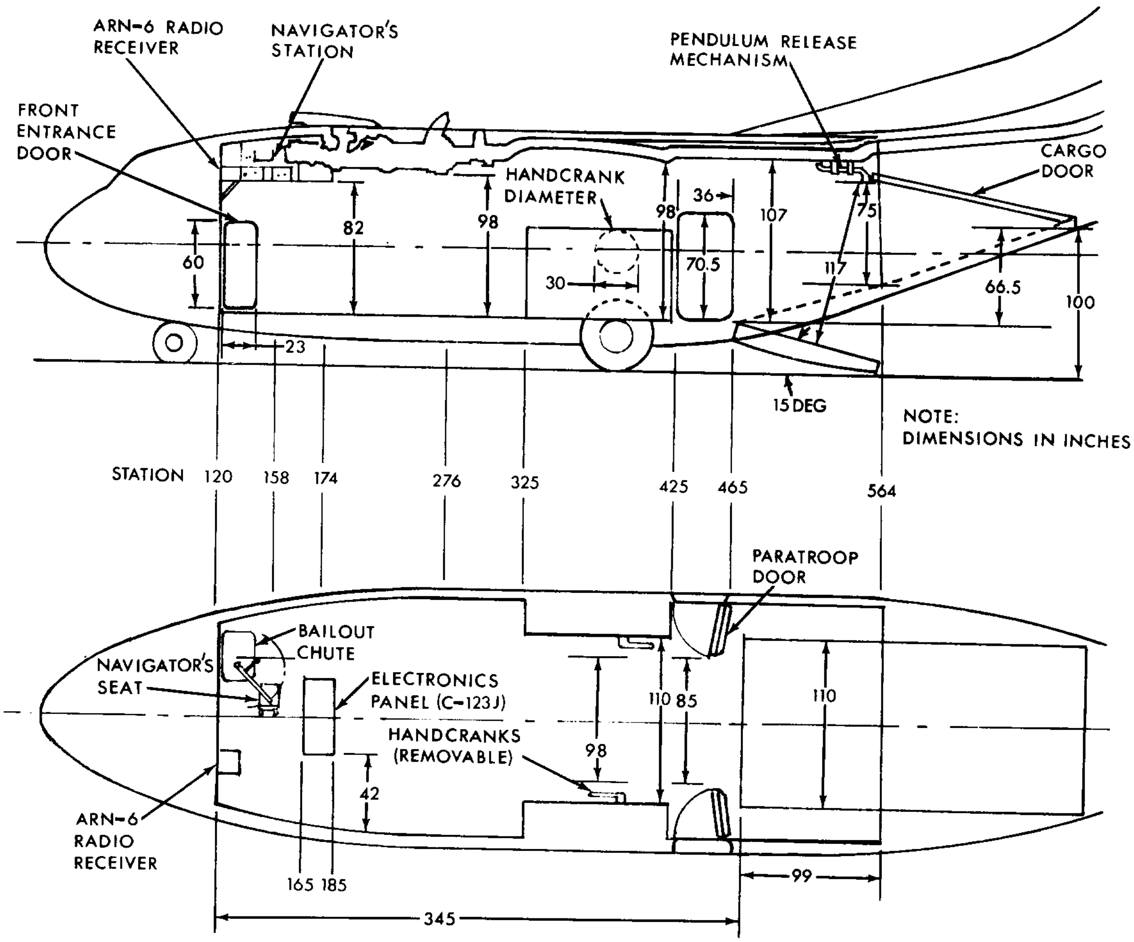
AIRCRAFT	TYPE	MAIN CARGO COMPARTMENT (USABLE SPACE)			MAIN LOADING APERTURE			RAMP DATA GROUND ANGLE, deg	FLOOR ANGLE, deg	MISC.
		LENGTH, in.	WIDTH, in.	HEIGHT, in.	WIDTH in.	HEIGHT, in.	LENGTH, in			
707	F/W	1326	139	91	134	91	(1)	(1)	(1)	(2) (3)
C-123	F/W	444	110	98	110	117	100	15	15	(4)
C-124	F/W	884	136	139	(5)	140	333	17	11.5	(7)
C-133A	F/W	1168	141.6	158	(6)	144	189	9	9	(4) (2)
C-135	F/W	860	129	84	116.4	78	(1)	(1)	(1)	
C-141	F/W	840	126.6	109.2	123.6	109.2	133	14	14°	
C-5A	F/W	1453	228	162	228	162	271	(8)	(8)	(3)
CV-2	F/W	345	73.5	74	87	74	120	15	(1)	
CV-7A	F/W	373	92.5	78	(9)	68	(11)	15	(1)	
CH-21	H	240	50	62	45	59	(1)	(1)	(1)	(3)
CH-47A	H	366	90	78	90	78	(11)	13	(11)	(3)
CH-54A	H	144	84	84	(1)	(1)	(1)	(1)	(1)	(10)

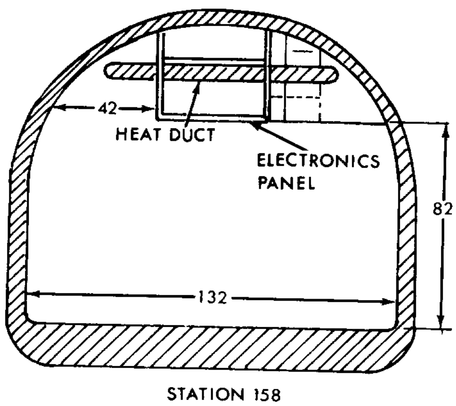
NOTES:

(1) Not Applicable
(2) Multiple Compartment
(3) Multiple Cargo Doors
(4) Station Limitations
(5) Tapers from 107 in. at Top to 136 in. at bottom
(6) Tapers from 112 in. at Top to 145 in. at bottom
(7) Two traveling cranes and two winch pulleys
(8) Variable by adjustment
(9) 92.1 in. at ramp hinge-82.3 in. at door hinge
(10) Cargo Pod
(11) Data not available

F/W - Fixed Wing

H - Helicopter





DESCRIPTION OF AIRCRAFT: The C-123B is a twin-engine transport designed to carry combat and other equipment for airborne assault troops. The cargo compartment is designed for easy loading at the aft end of the aircraft. The cargo ramp can be positioned from ground contact to any truck-bed height for loading bulky cargo or wheeled vehicles.

DIMENSIONS:

Main Compartment:
- Height (usable) . . . . 8 ft 2 in.
- Length (over-all) . . . . 36 ft 8 in.
- Width (at wheel wells) . . 9 ft 2 in.

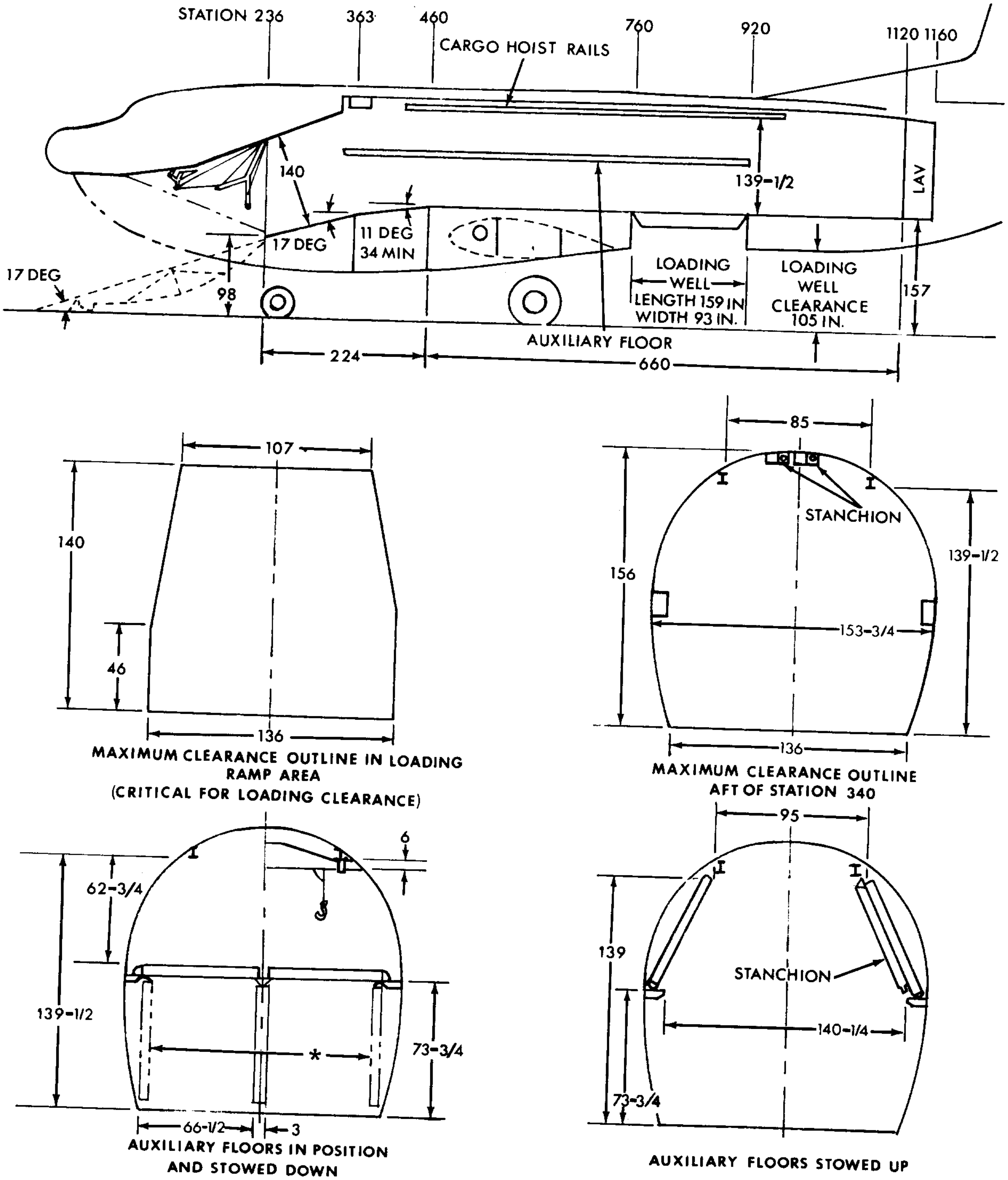
CAPACITY:

- Main Compartment (Volume) . . 3,570 cu ft
- Main Compartment (Area) . . . . . 450 sq ft

REFERENCE: (a) Technical Order 1C-123B-9
(b) Standard Aircraft Characteristics Book

TYPICAL LOGISTICAL MISSION: 1,000 Nautical Miles (one way) - Normal weight 11,785 lb.

Fig. 18-14. Cargo Compartment Dimensions and Contours, C-123 Aircraft (AF 54-647, 56-4362, and Subsequent)[15]



*
125 IN. STA 340—540 (AF 49-232 THRU AF 49-250)
131 IN. STA 540—1020 (AF 49-232 THRU AF 49-250)
131 IN. ALL STATIONS (AF 49-251 AND SUBSEQ)

NOTE:
DIMENSIONS IN INCHES

Fig. 18-15. Cargo Compartment Dimensions and Contours, C-124 Aircraft[15]

In addition to the load weight, allowance must be made for the weight of the air delivery system. To air drop a 3,500-lb load, approximately 700 lb of air delivery equipment are required; a 7000-lb load requires 900 lb of equipment; and a 16,000-lb load requires 3000 lb of equipment.

Containers rigged on air delivery platforms must allow a 5-in. lateral clearance and a 6-in. vertical clearance with the aircraft during loading and extraction. The container, when in contact with the platform, must be no wider that the distance between the outer tiedown rings on the platform.

18-4.5 COMBINATION OF CARRIERS

To promote maximum efficiency of distribution, a combination of the different modes of transportation is usually required. In order for the packaged item to be compatible with each mode of transportation selected, the most restrictive limitations of the combination are the determining factors in the packaged design. Three new concepts of transportation using a combination of carriers are described in pars. 18-4.5.1 to 18-4.5.3.

18-4.5.1 Roll-on/Roll-off System (Refs. 27 and 28)

One of the latest methods of solving the problem of efficient distribution is the use of the roll-on/roll-off system, in which the packaged item is carried in semitrailers from depots to an ocean terminal, rolled onto a specially designed vessel, rolled off the ship and on to its destination. The critical dimensions of the U.S. Army semitrailers used in the roll-on/roll-off systems are given in Table 18-12.

18-4.5.2 Trailer-on-flat-car (TOFC)

TOFC has become a safe and efficient means of transportation. The TOFC mechanical-type rail cars used for transporting the trailers are available nationwide and are readily obtainable. Presently, TOFC equipment can handle trailer lading weights up to 40,000 lb and can carry one or more trailers depending on the length of the flat car and trailer used. However, the highway limitations and minimum railroad clearances previously described must still be adhered to in order to permit efficient movement.

18-4.5.3 Trailer-containers-on-flat-car (Containerization)

The latest concept of efficient transportation is the use of containers that can travel by road, by rail, by air, or by sea. These containers have special fittings in which trailer dollies are attached for over the road travel. With the dollies removed, the container can be placed on flat cars, aboard ships, or aircraft. This allows the packaging engineer to take advantage of lower rates for rail, air and waterway traffic. However, this service is still partially restricted to CONUS, Canada, and Puerto Rico because of the limited equipment at overseas ports. West Germany, Japan, and the United Kingdom are rapidly advancing in providing container ships and facilities at dockside to extend the containerization concept of transportation.

The air freight system is rapidly becoming containerized. Approximately 60 automatic cargo facilities will be built throughout the world to expedite this method of goods transportation. New aircraft such as the Boeing 747 and the Lockheed 500 will be able to carry more than 100 tons of cargo. These aircraft and cargo handling systems will greatly expand the airlift capabilities for the movement of supplies.

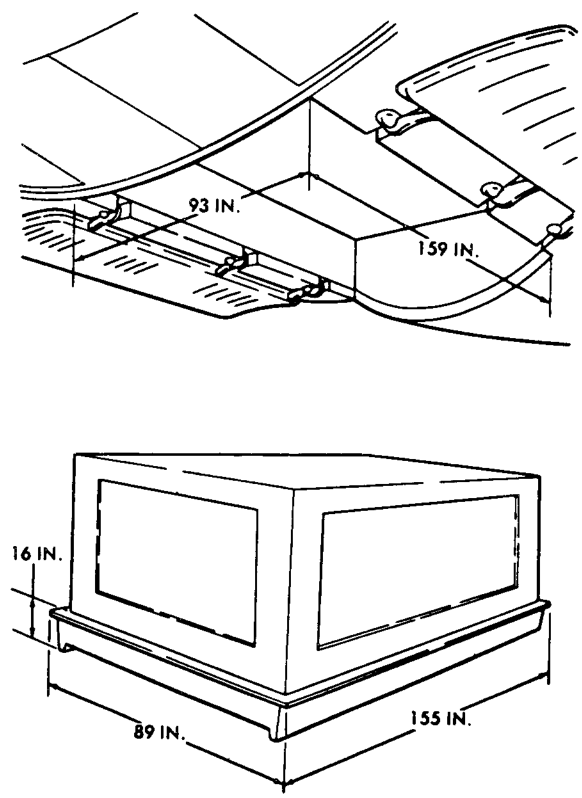


Fig. 18-16. Loading Well Clearance, C-124 Aircraft

18-5 STORAGE LIMITATIONS (Refs. 7 and 29)

After manufacture, the packaged item usually remains in storage until it is needed. While in storage, the packaged item must be protected from the adverse effects of the natural environment. Some natural storage spaces, such as cool, dry caves, provide ideal long-term storage for most items. However, man-made structures are the most common means for storing material since natural shelters are not commonly found. In some areas, no protection is available and the packaged item must be stored outside. The limitations imposed on the package by the types of storage, the required care and maintenance, the time in storage and item shelf life, the standard layout and dimensions for stored material, and the stacking requirements are described separately in pars. 18-5.1 through 18-5.5.

18-5.1 TYPES OF STORAGE

All military materiel must be packaged so that it is capable of withstanding the effects of extreme environmental conditions during storage. The various classes and types of storage that the packaging engineer must contend with are:

a. *Class A, Dormant Storage.* Packaged item is protected against the entry of the elements by preservation, sealing, covering, or placing in shelters and buildings, either dehumidified or nondehumidified. Items in dormant storage are not operated between reprocessing cycles.

b. *Class B, Active Storage.* Packaged item is protected by the same basic measures as dormant storage except certain preservation requirements are replaced or supplemented by specific periodic excercising either by running the equipment or by operating the equipment with an external power or driving source.

c. *Type 1, Outside of Buildings (Open) Storage.* Consists of a storage area exposed to the extremes of local, natural environments. The package must protect the packaged item from all the weather elements as well as from fungus, pests, dust, pilferage, and the unpredictable results of idle curiosity. When it is known that materiel will be in open storage, maximum utilization of known methods and materials is specified to insure the serviceability of the stored materiel. Constant surveillance and maintenance are required to prevent deterioration.

d. *Type 2, Sheltered Storage.* Consists of ventilated or unventilated, heated or unheated buildings, shelters, and closures of structural characteristics designed to

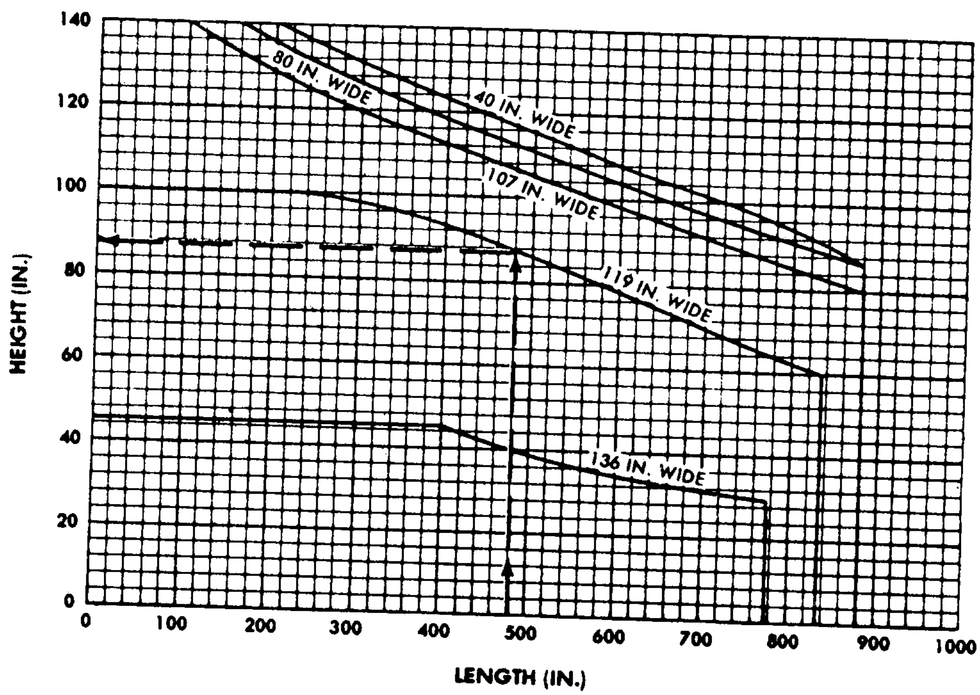
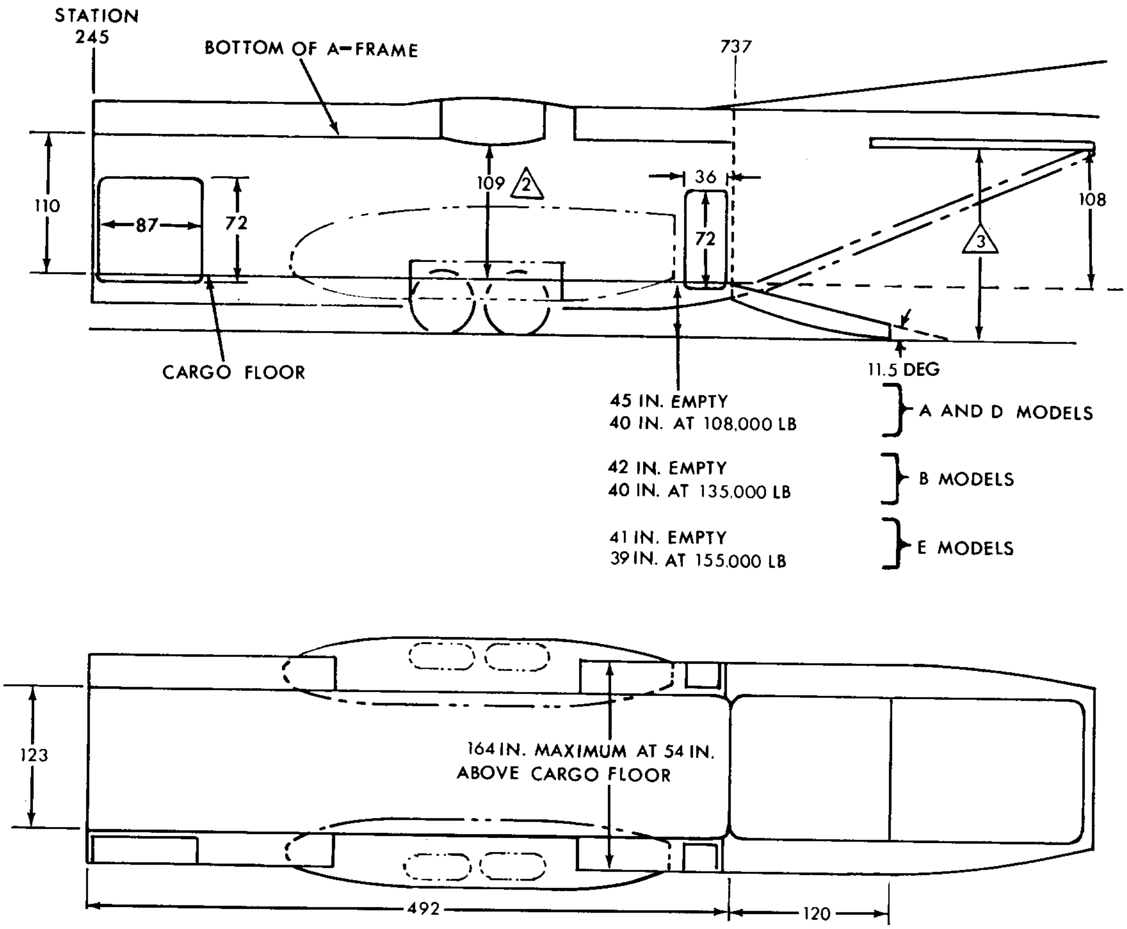


Fig. 18-17. Nose Loading Door Rectangular-crated Cargo Size Limits, C-124 Aircraft[15]



NOTE:
1 DIMENSIONS IN INCHES.

2 108 IN. WITH LITTER BRACKET INSTALLED.
WITH DUAL-RAIL AIRDROP SYSTEM INSTALLED DEDUCT 2.625 IN.

3 AIRCRAFT ON HARD SURFACE, LANDING GEAR STRUTS AT STANDARD INFLATION, NOMINAL DIAMETER TIRES 35 PERCENT DEFLECTION, THIS DISTANCE IS:

C-130A AND D: 146 IN. AT 108,000 LB.
C-130B: 147 IN. AT 135,000 LB.
382B AND C-130E: 143 IN. AT 155,000 LB.

DESCRIPTION OF AIRCRAFT: C-130A is a four engine mediumrange transport designed for high speed movement of personnel and material for delivery by parachute or landing as required. It features integral ramp and cargo door, crew and cargo compartment pressurization, ground and in flight air conditioning.

DIMINSIONS:
Main Compartment:
Height . . . . 9 ft 1 in.
Length . . . . . . 41 ft 5 in.
Width . . . . 10 ft 4 in.

Ramp:
Incline . . . . . . 13°

CAPACITY:
Main Compartment (Volume) . . . . 3708 cu ft
Main Compartment (Area) . . . . . . 420 cu ft

TYPICAL LOGISTICAL MISSION : 1, 000 Nautical Miles (one way)- Normal weight 29, 500 lb.

Fig. 18-18. Cargo Compartment Dimensions, C-130/382B Aircraft[15]

afford protection from the elements. The stored materiel is not protected from atmospheric changes of temperature and humidity. Periodic surveillance and maintenance are required to keep deterioration to a minimum.

e. *Type 3, Dehumidified Structural Storage.* Consists of structures in which the atmosphere is maintained at a relative humidity of 40 percent or less. Controlled humidity storage in structures provides the highest degree of protection and is the most economical method of storage for items of a critical nature since little surveillance and maintenance is required.

f. *Type 4, Dehumidified Nonstructural Storage.* Consists of complete or partial sealing of the packaged item with a mechanical or static dehumidification of each item, singly or in series, in which the relative humidity of the atmosphere within the interior areas does not exceed 40 percent. Controlled humidity storage of individual items requires the surveillance of individual items to ensure constant protection.

The storage of explosive material (Refs. 31, 32) is controlled by the potential hazards of the materiel. Materiel of an explosive nature must be stored in standard ammunition magazines designed for these purposes, or in areas designated specifically for the storage of explosives, ammunition, or loaded components. These areas are usually not wired for electricity and generally are not heated. The packaged item must be adequately preserved to protect it from deterioration. The outer package must be labeled to identify the contents as explosive. The package should be designed to facilitate inspection required by periodic monitoring and surveillance without cover removal.

18-5.2 INSPECTION, CARE, AND PRESERVATION DURING MAINTENANCE

The package must be designed for easy inspection either through unpacking and repacking or through the use of windows, ports, access hatches, or removable container sections. The package must be adequately labeled so that regardless of how the package is positioned, the identification labels are readily accessible. To aid in inventory control, the same number of units should be packed in any one size container so that a count can be taken without referring to the identification label on each container.

The need for care and preservation of packaged items during storage can be reduced to a minimum by proper design. In packaging design, only the best and most durable materials should be used consistent with economy. Most materiel sent for storage are placed in dormant storage, where they are completely immobilized until they are required. Dormant storage usually lasts from one to three years, depending on the need for inspection and for renewing the preservative coating. Many items, especially mechanical equipment, must be kept in active storage where they can be exercised every 60 to 90 days. This is necessary in order to redistribute the preservatives over critical surfaces. The features of active and dormant storage are given in Table 18-13.

Some of the trouble spots that have been uncovered during the inspection, care, and representation phase of storage are:

a. Excessive run-off of preservatives on critical interior operating surfaces, requiring frequent renewing

b. Electrical components not readily accessible for preservation without disassembly and unsoldering of components

c. Frequent need for sealing of exterior openings opened during inspection

d. Requirements for packing large voids such as grilles, louvers, and openings with waterproof barrier materials

e. Name plate treatment to maintain legibility and transparency and to prevent corrosion

f. Packing material that cannot be used to repack an item after it is unpacked, requiring extensive new material for repacking

g. Packages and packs that must be repacked or strengthened to meet the minimum packing requirements for overseas shipment.

18-5.3 TIME IN STORAGE AND SHELF LIFE

The packaging engineer usually must design the package so that is is capable of protecting the packaged item throughout the whole storage time without the need for repackaging. The length of time the item remains in storage is based on many factors, principally the demand and the shelf life. For food, rubber products, chemicals, certain drugs, and many other items that deteriorate rapidly, the shelf life is the governing factor. The package design for those items should be based on the expected shelf life of the material in order to effect maximum economy of packaging materials.

18-5.4 STANDARD LAYOUT AND DIMENSIONS FOR STORED MATERIAL

Storage space limitations depend on the dimensions of the building, elevators, entrance ways, and materiel handling equipment. For many commodities there are no standards for these limits, hence they must be determined for each individual case. However, regardless of the size and configuration of the storage area, definite headspace and aisle widths are required (Ref. 31). Aisle widths in storage depots are usually between 10 and 12 ft, where standard fork-lift trucks are used, but may be reduced to only 6 ft when straddle-type trucks are available. Dimensions and weight limitations are also placed on packages by the load limits of the handling equipment (par. 18-6).

Storage space limitations also involve bin and shelf box sizes for small packages. Standard Department of Defense bin sizes are shown in Fig. 18-32. The dimensions of the metal shelf boxes that fit in these standard bins are also shown. Whenever practical, the packaging engineer should strive to fit the packaged item in an outside package that can be placed in these bins.

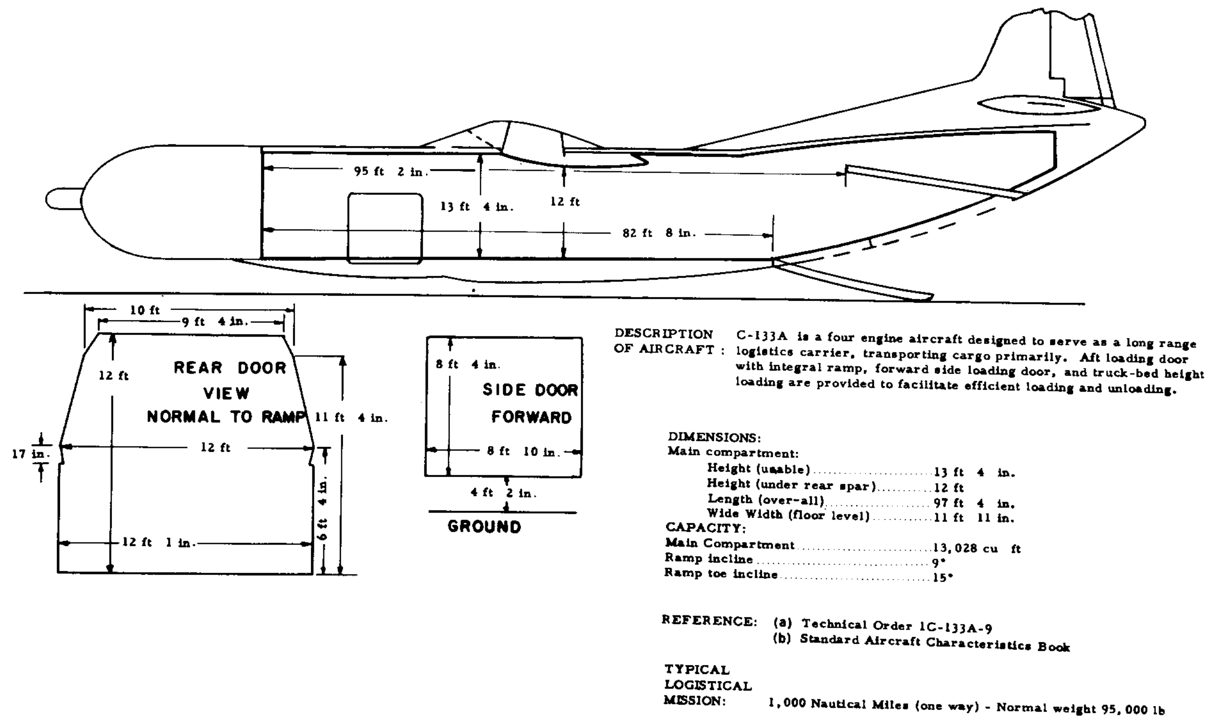


Fig. 18-19. Cargo Compartment of C-133A Aircraft[15]

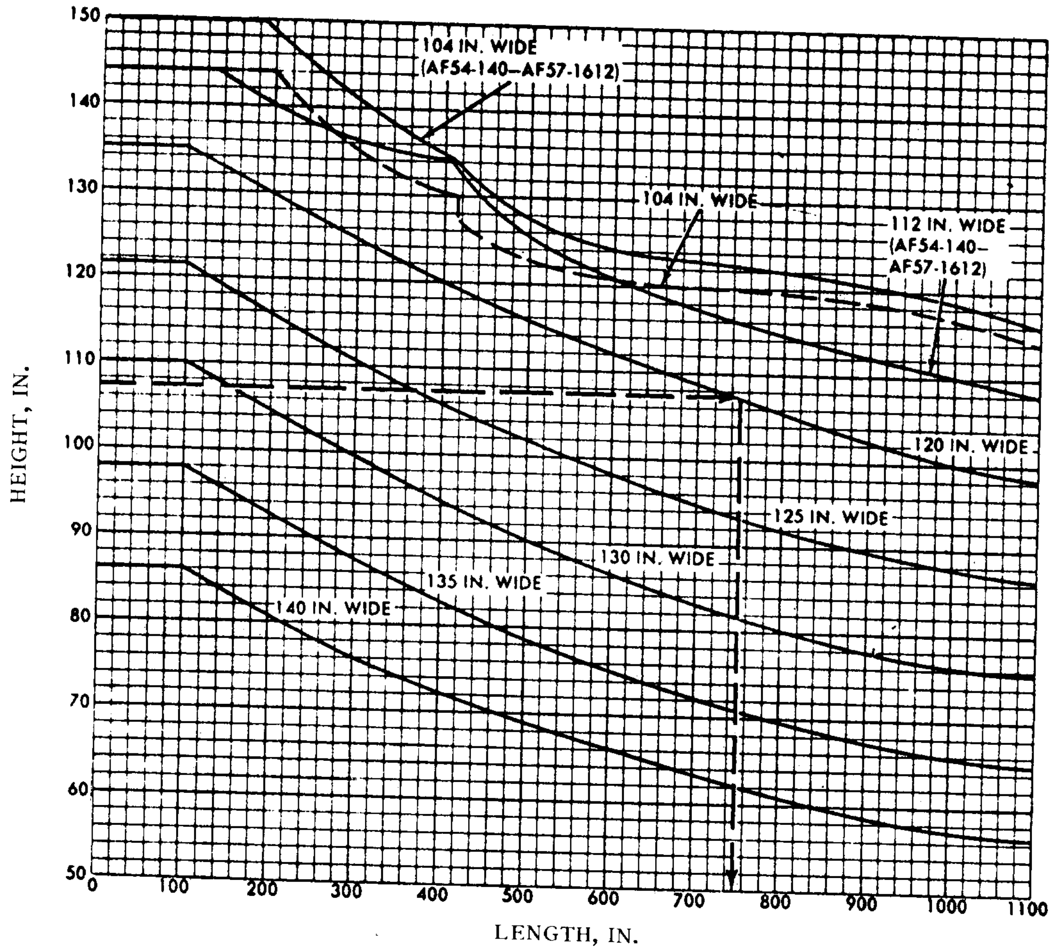


Fig. 18-20. Main Cargo Door Package Size Graph, C-133A Aircraft[15]

TABLE 18-8
HELICOPTER EXTERNAL-LOAD CAPACITIES[15]

HELICOPTER	WEIGHT OF LOAD, lb
UH-1A	3,000
UH-1B	3,500
UH-1D	4,000
CH-21	5,000
CH-34	5,000
CH-37B	8,000
CH-47A	16,000
CH-54A	20,000

TABLE 18-9
PAYLOAD DATA FOR SELECTED ARMY AIRCRAFT WITH INTERNAL CARGO LOAD ONLY[16]

Airplane	Type	100 Nautical Mile Range Mission lb	100 Nautical Mile Radius Mission, lb	350 Nautical Mile Range Mission, lb
U-1A	Fixed Wing	2580	2450	2250
YAC-1	"	6100	5300	5200
H-21	Helicopter	3000	2450	
H-34	"	3100	2500	
H-37	"	5600	4000	
HU-1A	"	800	650	

TABLE 18-10
RESTRAINT DATA FOR AIR TRANSPORTED PACKAGES[15] (expressed in units of gravity "g's")

TYPE	FWD	AFT	SIDE	VERT	TYPE	FWD	AFT	SIDE	VERT
707	9.0	4.5	1.5	2.0	C-5A	(1)	(1)	(1)	(1)
C-123	8.0	2.0	1.5	4.5	CV-2	8.0	2.0	1.5	2.0
C-124	3.0	1.5	1.5	2.0	CH-21	8.0	2.0	1.5	2.0
C-133A	3.0	1.5	1.5	2.0	CH-47A	4.0	2.0	1.5	2.0
C-135	8.0	1.5	1.5	2.0	CH-54A	(2)	(2)	(2)	(2)
C-141	8.0	1.5	1.5	2.0					

NOTES: (1) A general 3.0 g cargo restraint load factor is being utilized.
(2) External Pod.

FWD - Forward VERT - Vertical

AIR DELIVERY RESTRAINT

Rigged platforms shall be restrained to the aircraft floor with tiedown devices to the following criteria:

FORWARD	AFT	SIDE	VERTICAL
4.0 g's	1.5 g's	1.5 g's	2.0 g's

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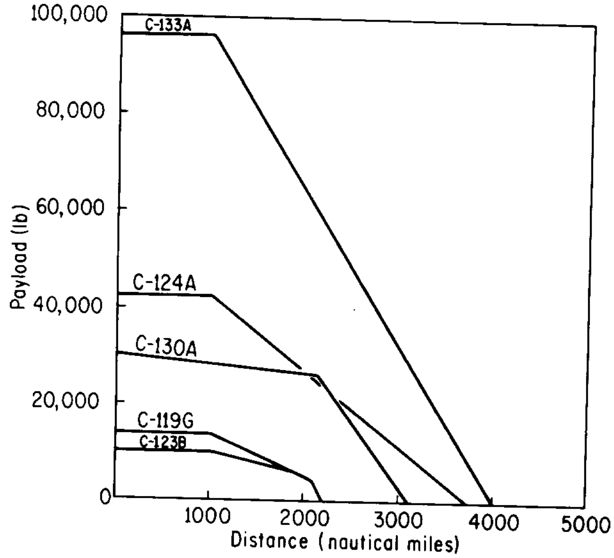


Fig. 18-21. Normal Strategic Air Lift Missions, Refueling Available at Destination

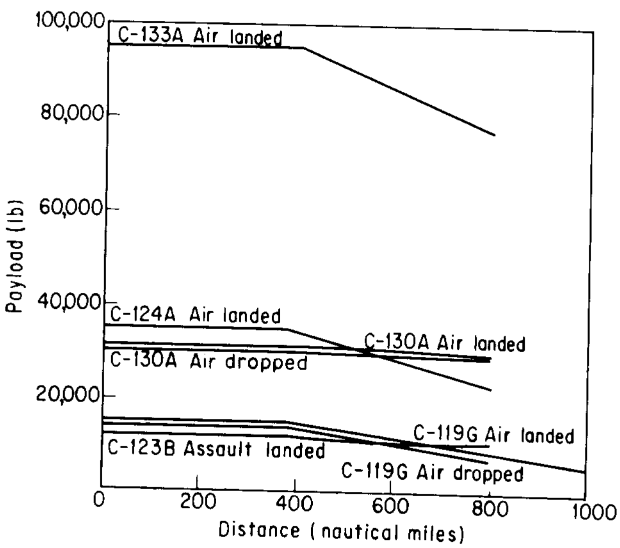


Fig. 18-22. Normal Tactical Radii Mission–Cargo Air Dropped or Air Landed, No Air-lead Refueling[15]

18-5.5 STACKING REQUIREMENTS

To conserve space and reduce costs in shipping, storing, and handling, packages are usually stacked two or more tiers high, depending on their size and weight. Requirements for stacking must be considered during package design. The package must be designed to be stable with no tendency to tip. This is usually done through the use of a rectangular end profile and wide skid spacing. Additional stability and easier stacking can be obtained by using positive design features (see Chapter 10) to prevent the slipping and sliding of one container stacked on another. Manufacturing tolerances at the location of these features are usually liberal (within 0.25 in.), but care must be taken to avoid tolerance accumulations that could interfere with the proper engagement of mated fittings on stacked containers.

Stability of stacks and the alignment of containers are particularly critical in rail and highway transportation. To prepare the packaged items for shipment, the load must first be unitized. It must be made up in such a way that it becomes, in effect, one solid mass rather than a number of separate items. Most containers are designed with tie bars to fasten one container to another in unitizing the load. In addition to their unitizing function, the tie bars on some containers provide the only restraint to longitudinal shifting of the stacked containers. As a result, the tie bars or their bolts sometimes bend or break, allowing the load to shift even when the containers are strapped together with steel straps. However, when the design features for positive positioning and alignment of stacked containers are provided, the tie bars are satisfactory since they are not subjected to any vertical force. Supplemental steel strapping is used only to unitize the load and to prevent vertical movement of the containers.

When tie bars are used, they must be provided with elongated or enlarged bolt holes at one end to compensate for dimensional variations among containers (Fig. 18-33(A)). This increases the possibility of slippage since the holding ability depends on the friction among the bold head, the tie bar, and the containers. A better method of unitization without the need for supplemental steel strapping can be accomplished by bolting through the skid of one container and the stacking pad of the container below (Fig. 18-33(B)). With this method, the holding ability depends on the tensile strength of the bolts and the shear strength of the threads. The bolts or nuts should be self-locking and capable of repeated assembly and disassembly without impairment of their locking ability. Whenever possible, weldnuts should be used so as to prevent the accidental loss of the nut and to permit rapid assembly and disassembly. Whichever method is used, either tie bars or direct bolting, the bolt heads should be readily accessible, although still within the basic rectangular profile of the unit.

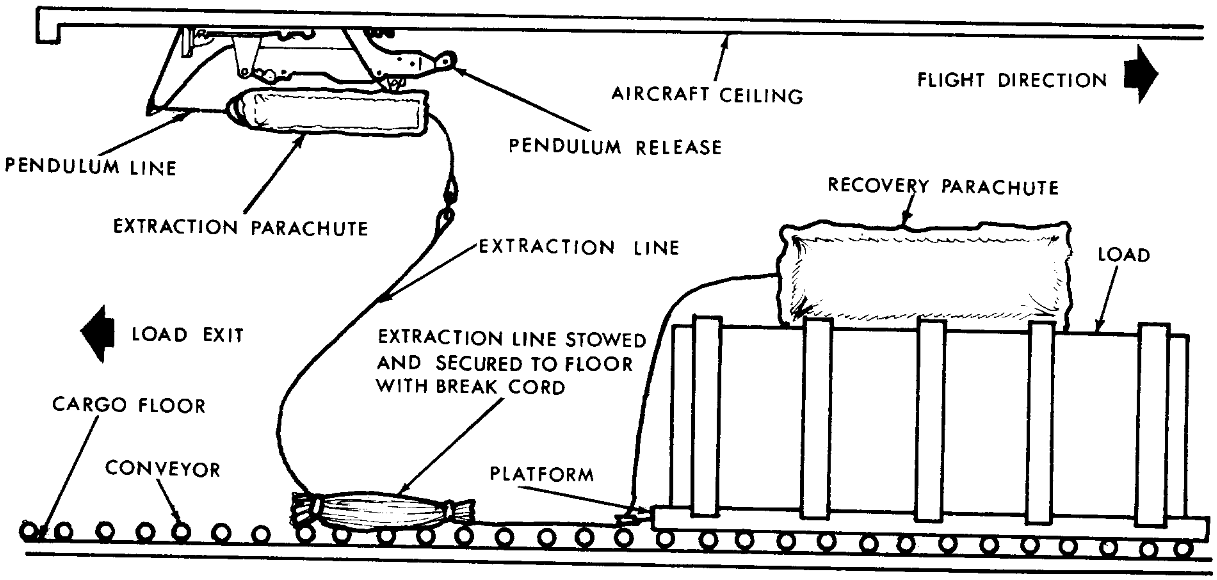


Fig. 18-23. Extraction Parachute Installed in Pendulum Release[15]

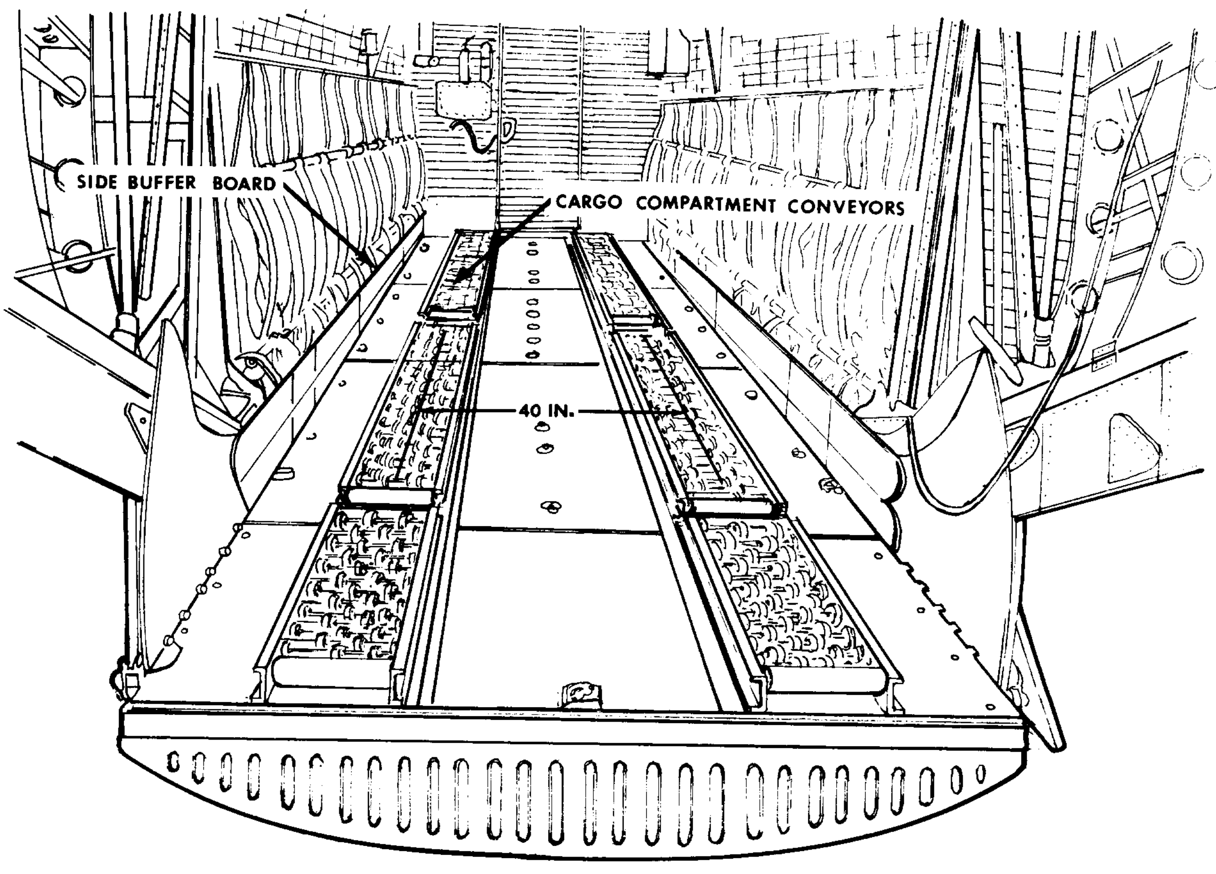


Fig. 18-24. Skate Wheel and Buffer Board System[15]

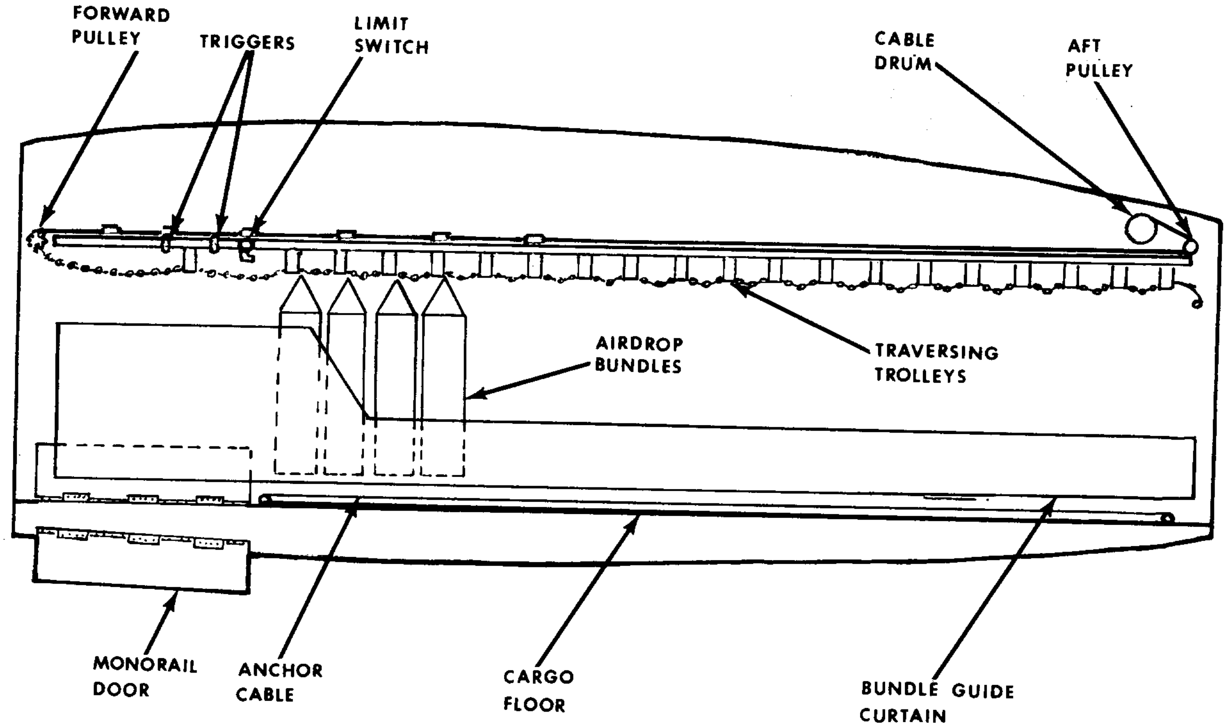


Fig. 18-25. Overhead Monorail System[15]

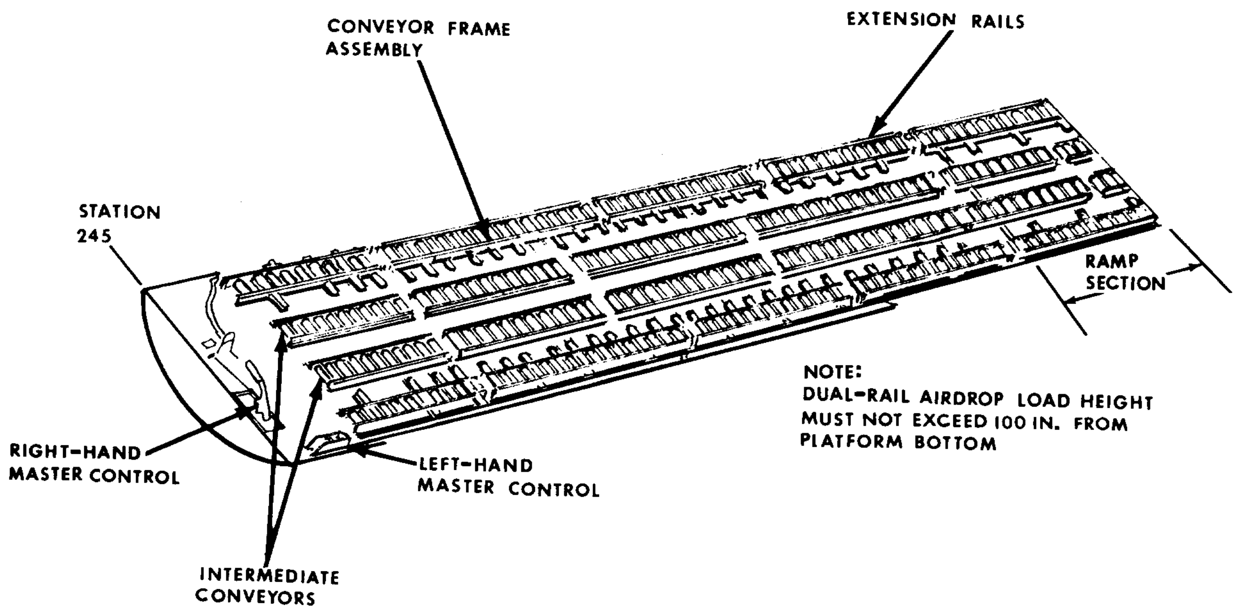


Fig. 18-26. Model AF/A32H-1A Dual-rail System Components[15]

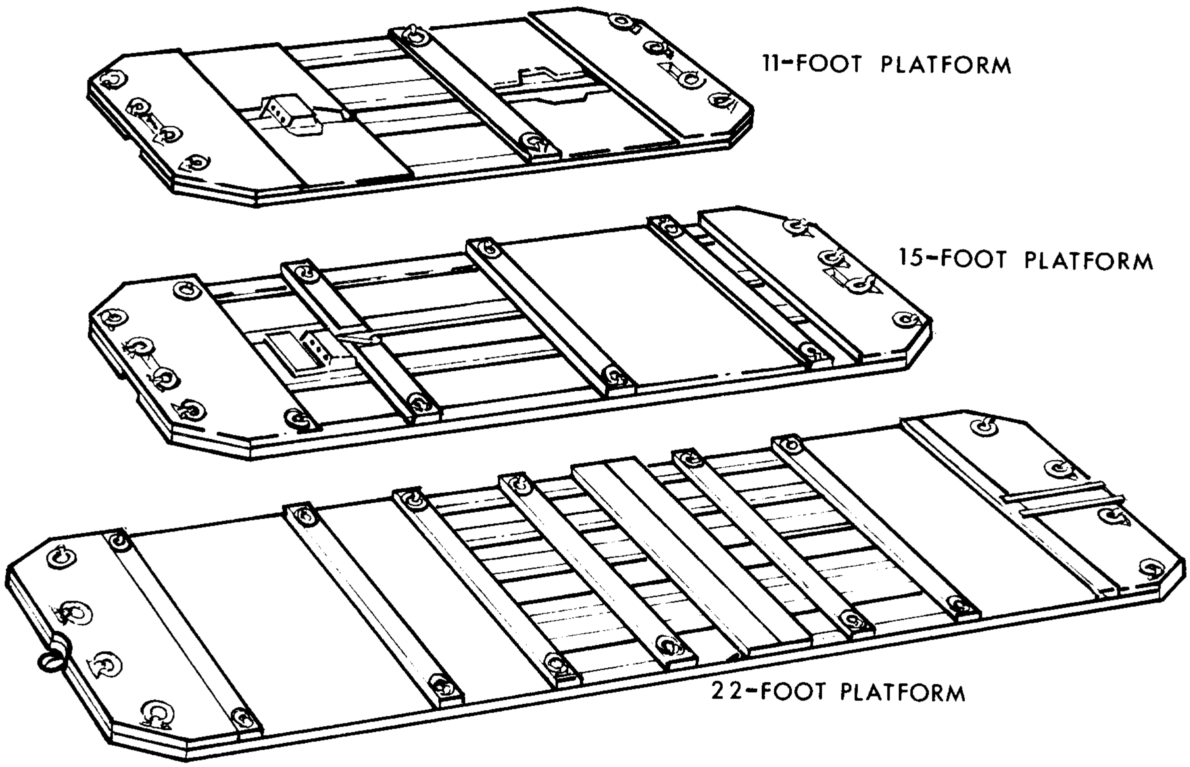


Fig. 18-27. Standard B Platform[15]

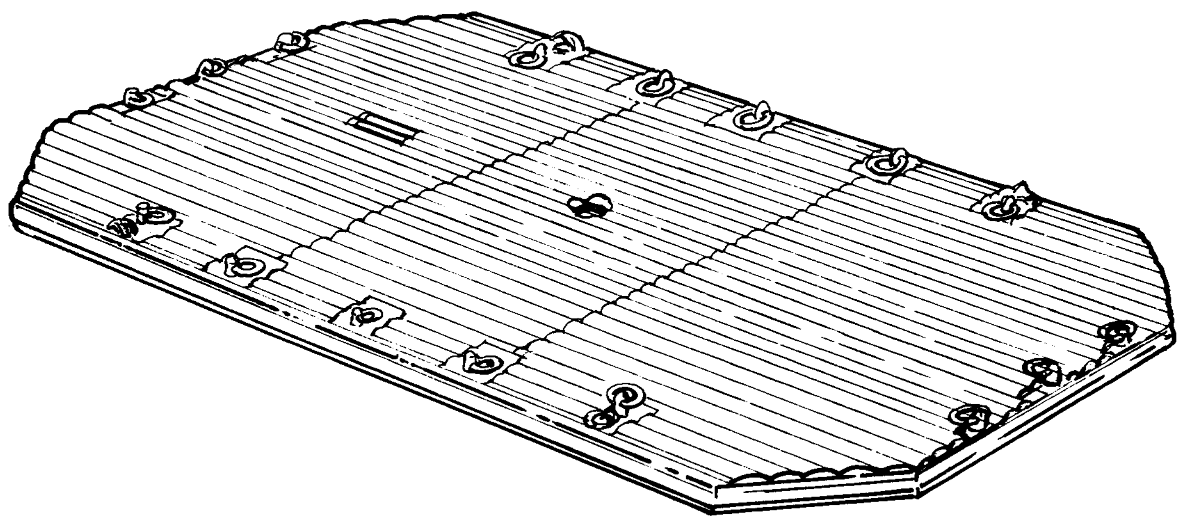


Fig. 18-28. J-1 Platform[15]

18-6 HANDLING LIMITATIONS (Refs. 7, 33-36)

Throughout all phases of transportation and storage, the packaged item is continually in the process of being handled. In order that the package may be easily handled, the packaging engineer must observe the limitations placed on the package by the handling equipment. The size and weight of the package should be such that it can be handled efficiently by standard military equipment. The packaging engineer must avoid the requirement for special vehicles or new handling equipment. The limitations imposed on the package by the type of handling equipment, terminal and port facilities, amphibious operations, and human factors considerations are covered separately in pars. 18-6.1 and 18-6.4.

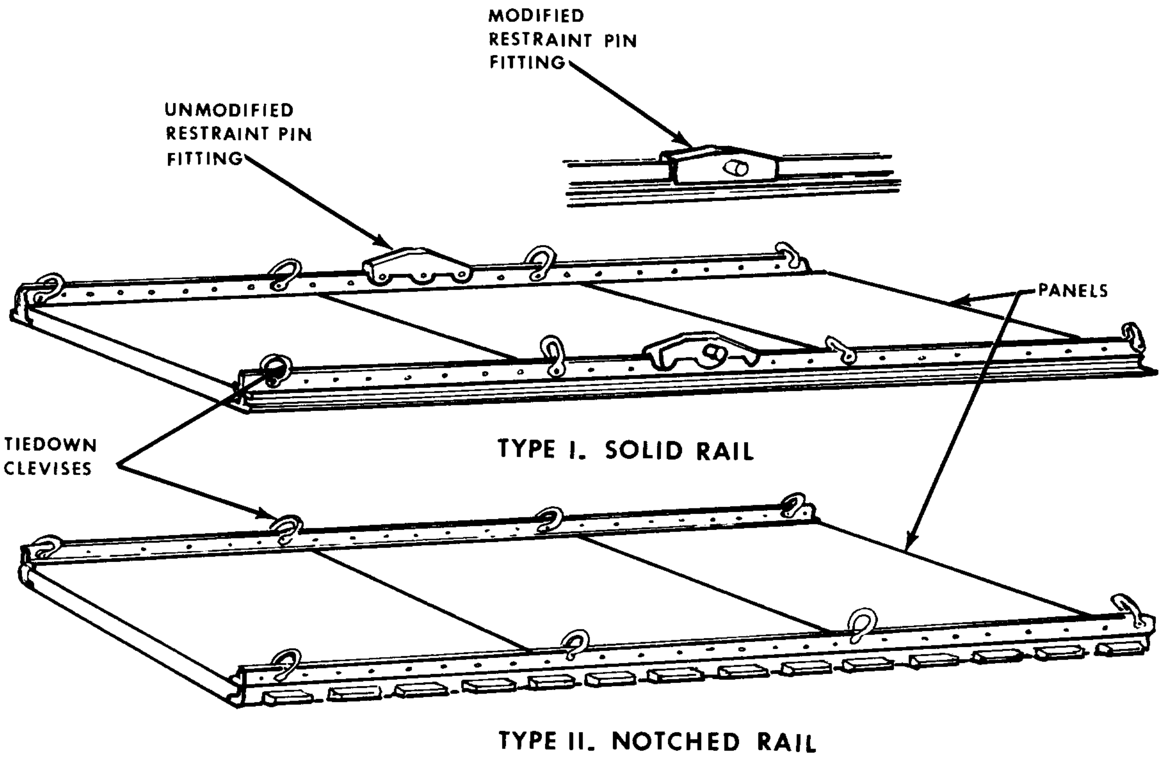


Fig. 18-29. Aluminum Modular Platforms[15]

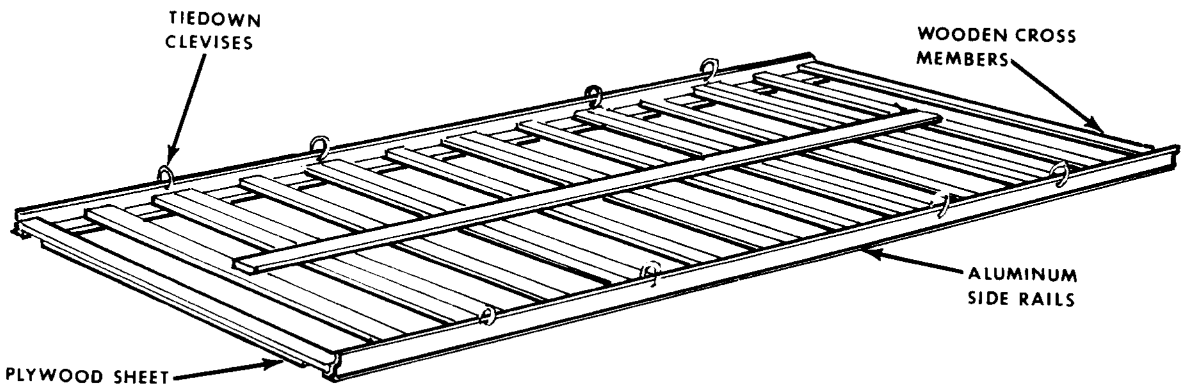


Fig. 18-30. Wooden Modular Platform[15]

18-6.1 HANDLING EQUIPMENT

The standard types of materiel handling equipment that may be used with a package at the various cargo handling installations are:

a. Self-propelled equipment consisting of fork-lift trucks, wheeled warehouse tractors, warehouse truck cranes, hand-lift pallet trucks, fixed platform trucks, straddle-carry trucks, overhead and gantry cranes, and hoists

b. Nonpowered mobile equipment consisting of platform warehouse trailers, hand trucks, and dolly trucks

c. Conveyors, including portable belt-types, roller gravity and wheel gravity types

d. Pallets made of wood or metal.

The packaging engineer must be certain the package can be handled by a combination of these common pieces of handling equipment. If necessary, two or three pieces of equipment can be used together to lift extremely long or heavy packages. The package should be clearly marked showing the handling locations such as lifting eyes, handles, rings, brackets, and center of balance. Lifting eyes should be permanently attached and large enough to accept rigging cable hooks. They should also be far enough above the center of gravity of the package to stabilize it. Handles should be so positioned that they will not catch on other units, cables, lines, structural members, etc. If the container is too awkward or heavy for manual lifting, some method of mechanical handling must be provided. To permit handling by fork-lift trucks (Fig. 18-34), the bottom of the package should be raised 3 inches above the floor. This is usually accomplished through the use of skids spaced to allow for the entry of fork-lift tines (Table 18-14). Reinforced channels should be constructed at the bottom of the package to prevent the fork tines from damaging the package wall. Two fittings should be located at the end of the package adjacent to the skids for use in moving the package.

18-6.2 TERMINAL AND PORT FACILITIES

The capabilities of handling equipment available to terminals and ports located in the United States are almost unlimited. Fork-lift trucks ranging from 2,000- to 15,000-lb capacity are usually standard equipment at most terminals and ports. Overhead transverse cranes for loading and unloading trucks and rail cars are available at many of the terminals and ports, and will usually range from 1- to 10-ton capacity, although there are larger ones in use. Portable cranes for both land and water are available which have capacities over 150 tons. For moving and stacking the heavier containers and palletized loads on board ship, fork-lift trucks are used along with the ship's gear. Due to the limitations of hatch sizes and available space in compartments and holds for maneuvering, fork-lift trucks are usually limited to the 4,000-lb capacity. Heavier loads may be handled by utilizing two fork-lift trucks. The size of fork-lift trucks used for loading and unloading railroad

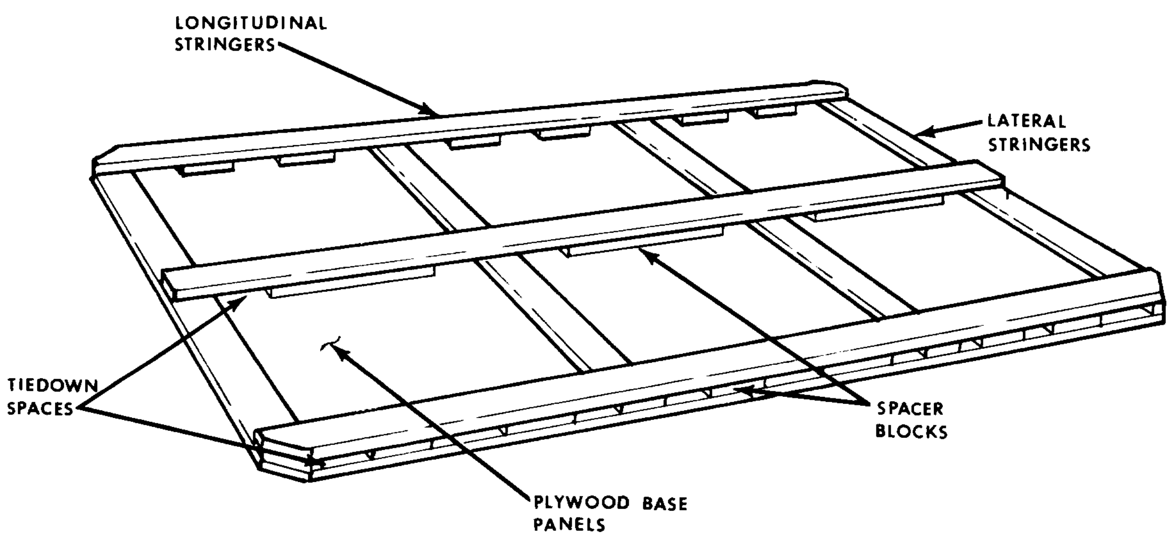


Fig. 18-31. Typical Combat Expendable Platform[15]

TABLE 18-11
DIMENSIONS AND WEIGHT LIMITATIONS FOR COMBAT-EXPENDABLE PLATFORMS[15]

LENGTH, ft	WIDTH, in.	WEIGHT* lb	SQUARE FEET	MINIMUM RIGGED WEIGHT†, lb
‡12	70	312	70	2450
12	96	407	95	3325
12	104	468	103	3605
12	107	474	106	3710
16	96	480	127	4445
16	104	568	137	4795
16	107	581	139	4865
18	96	643	143	5005
18	104	759	155	5425
18	107	772	160	5600
20	96	709	159	5565
20	104	819	172	6020
20	107	833	177	6195
22	96	815	170	5950
22	104	931	190	6650
22	107	950	195	6825
24	96	877	191	6685
24	104	1048	207	7245
24	107	1068	214	7490

* Figures based on No. 1 common soft lumber
2 x 4 – 1-3/4 pounds per lineal foot
2 x 6 – 2-1/2 pounds per lineal foot
2 x 8 – 3-1/4 pounds per lineal foot
2 x 10–4-1/2 pounds per lineal foot

† Size, weight, square footage, and loading weights required for combat-expendable platforms computed at 35 pounds per square foot.

‡ First row pertains primarily to CV-2 aircraft.

box cars is usually limited by the door sizes of the box cars. These door sizes vary among cars (par. 18-4.2).

Facilities of overseas terminals and ports are usually more limited than those for the United States except for the larger and busier ones. Some of the smaller and less used terminals and ports may not be equipped with any mechanized equipment system. Shoreside facilities for train-ship, trailer-ship, and container-ship services are given in Ref. 34.

18-6.3 AMPHIBIOUS OPERATIONS

In some instances, landing craft and amphibious vehicles may be used for the transportation of packaged items. This type of transportation is commonly used in time of war for beachhead landings, but may also be used in peacetime. It may be used for the transfer of cargo between ships and port facilities where, due to the location and physical aspects of the port, ships cannot dock. The ship's facilities will usually be used for loading and unloading the ship, while the available shore facilities will be used for loading and unloading the landing craft and amphibious vehicles on shore. The shore facilities may consist of anything from manual labor to the equipment listed under handling equipment.

18-6.4 HUMAN FACTORS CONSIDERATION

The human factors considerations should be recognized by the packaging engineer and provided for in the preparation of the package when these requirements do not conflict with the packaging requirements and the design of the packaged item. The packaging engineer is severely limited in the changes he can make to the weight, size, and movability of the package and pack-

aged item. However, through the use of mechanical aids, such as handholds, hook eyes, and skids on the package, the handling qualities of the packaged item can be much improved (Ref. 37).

18-7 SUPPLY CLASSIFICATION OF ITEMS (Ref. 30)

In order to segregate the entire range of items that flow through the supply system, categories have been devised based on the nature of the item, its importance to supply needs, or its behavior in the supply system. The break-down of the items by nature and importance follows:

a. *Principal Items.* Table of Equipment items, the supply of which is, or is about to be, increasingly active, a high value item; or an item whose procurement will be difficult due to long lead time, shortage of strategic materials, or difficulty of manufacture. Principal items represent less than 1 percent of the items stocked by the Army yet account for 60 percent of the procurement funds.

b. *Secondary Items.* Consist of all other supplies, except repair parts, clothing, and subsistence, and are characterized by short lead times, low value, and ease of procurement.

c. *Repair Items.* All essential elements, materials, components, assemblies, or subassemblies required for the maintenance and repair of an item.

d. *Off-the-shelf Items.* Items regularly stocked by commercial organizations to supply normal demands; either principal, secondary, or repair items.

e. *Bulk Procurement Items.* Items normally shipped in bulk form, and not sent through depot facilities; usually secondary items.

TABLE 18-12
EQUIPMENT DIMENSIONS OF THE U.S. ARMY SEMITRAILERS USED IN THE ROLL-ON/ROLL-OFF SYSTEM[27]

Item	Van Model 220 KAK (l x h x w)	Van Model SKD 3809 (l x h x w)	Stake and Platform Model M127A1 and C1 (l x h x w)
Outside Dimensions	27' x 11' x 8'	26'5" x 11'6" x 8'	28'8" x 9' x 8'
Inside Dimensions	26' x 6'5" x 7'5"	25'10" x 6'8" x 7'6"	27'11" x 4' x 7'5"
Overall Height (Top of rack)	11'	11'6"	9' (may be loaded higher)
Gross Cubic	2376 ft^3 59.4 MTON$^{(2)}$	2430 ft^3 60.8 MTON$^{(2)}$	2087 ft^3 51.6 MTON
Capacity Weight STON$^{(1)}$	18	12	18
Capacity Cube MTON$^{(2)}$	31.1	32.3	20.7
6" above top			23.3
Tare Weight, lb	10,500	8700	14,200

Notes:

(1) STON - Short ton; one short ton equals 2,000 lb

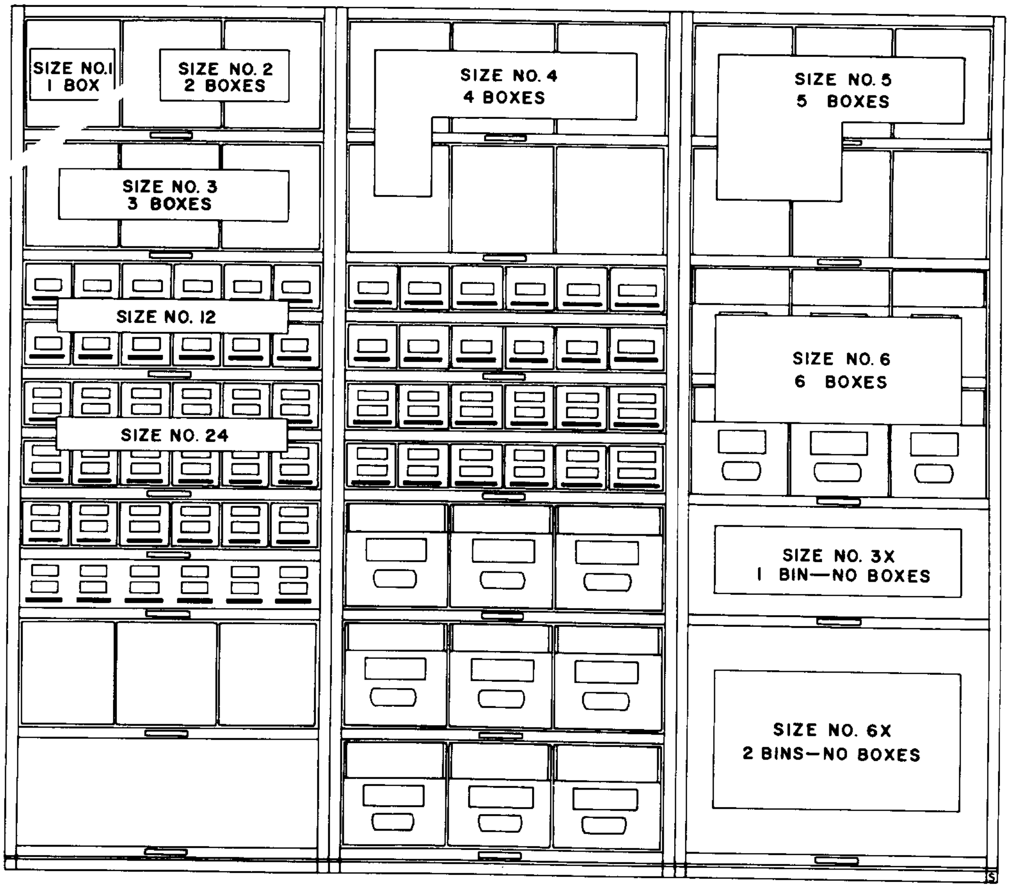
(2) MTON - Measured ton; one measured ton equals 40 ft^3

TABLE 18-13
FEATURES OF ACTIVE AND DORMANT STORAGE

Active Storage	Dormant Storage
Advantages	
(1) Lower initial cost.	(1) Lower overall cost.
(2) Redistributes lubricants and revitalizes perishable parts such as grease seals, gaskets, etc.	(2) Complete preservation and sealing of each component.
(3) Prepared for activation on short notice.	(3) Unit is immobilized, can be adequately protected by outer package.
Disadvantages	
(1) Requires periodic operation.	(1) High initial cost for complete preservation.
(2) Component parts which are not involved in redistribution of lubricants are not completely preserved.	(2) Preservatives tend to drain off or flow from critical surfaces.
(3) Exercising generates harmful products such as carbon, acids, water, etc.; cannot be securely protected by outer package.	(3) Requires long time for depreservation to prepare for immediate use.

TABLE 18-14
SAMPLE SIZE AND LOAD CAPACITY OF TRUCK, FORK-LIFT, ELECTRICAL CONVENTIONAL OR SPARK ENCLOSED, SOLID TIRES

Size	Load Capacity, lb.	Lift Ht., in.	Collapsed Mast Ht., in.	Free Lift, in.	Fork Length, in.
I	2,000	100	68	42	36
II	2,000	127	83	57	36
III	4,000	100	68	42	40
IV	4,000	127	83	57	40
V	4,000	144	91	57	40
VI	6,000	127	83	57	40
VII	6,000	168	113	6	40
VIII	4,000	144	72	22	40
IX	6,000	100	68	42	40
X	8,000	118	83	15	40



1. Space size 1 requires 1 large shelf box (17-1/2" x 11-1/4" x 10-3/8" h).
2. Space size 2 requires 2 large shelf boxes.
3. Space size 3 requires 3 large shelf boxes.
4. Space size 3X does not require shelf boxes but comprises 1 complete shelf space.
5. Space size 4 requires 4 large shelf boxes.
6. Space size 5 requires 5 large shelf boxes.
7. Space size 6 requires 6 shelf boxes as shown in figures 6 and 7 (3 each or 2 shelves).
8. Space size 6X does not require shelf boxes but comprises 2 complete shelf spaces.
9. Space size 12 requires a one-compartment shelf box (17" x 5-1/2" x 4-1/2 h).
10. Space size 24 requires 1 compartment of a two compartment shelf box (8-1/2" x 5-1/2" x 4-1/2" h).
11. Space sizes defined may be occupied by shelf boxes, loose material, or individually boxed material.

Fig. 18-32. Bin Sizes[31]

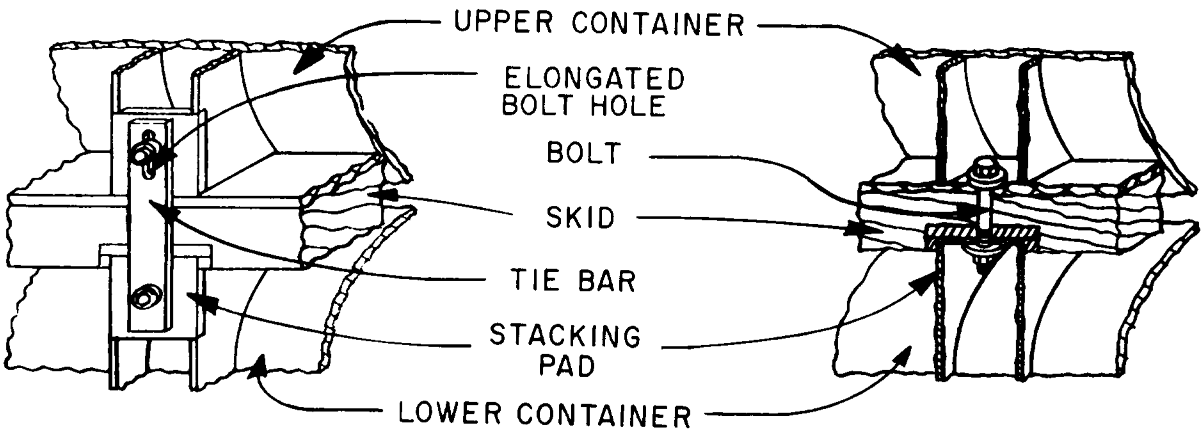


Fig. 18-33. Unitizing With Tie Bars and Direct Bolting[7]

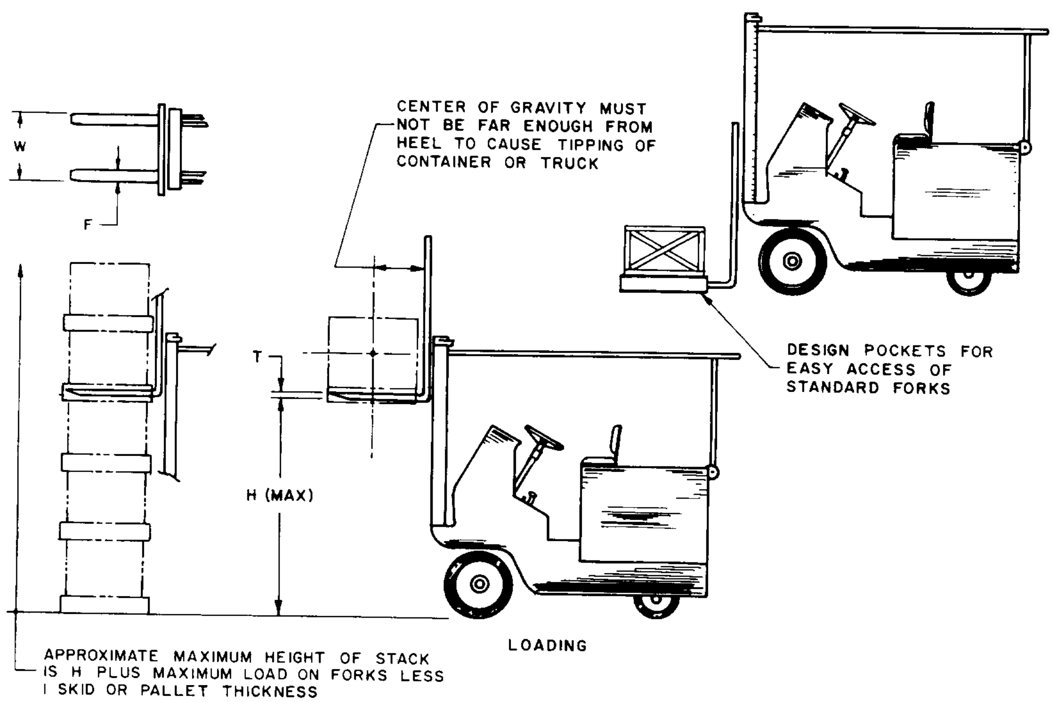


Fig. 18-34. Fork-lift Truck Limits[32]

Together, the secondary and repair items represent 85 percent to 90 percent of the entire workload and costs of the distribution system yet only account for 25 percent of the procurement funds. It is with these items the greatest economy can be effected through the use of advanced packaging techniques.

Items can also be classified by their behavior in the supply system: either fast moving or slow moving. The turnover of an item is important to the packaging engineer from the standpoint of over-packaging. Since fast moving items are readily depleted, it is not usually necessary to extensively wrap the individual units within the outer package. In addition, a large number of units can be packed for each station, resulting in a significant decrease in the total packaging effort and material required.

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APPENDIX A

RELATIONSHIP OF U.S. MILITARY PACKAGING TO MUTUAL SECURITY ORGANIZATIONS

Agreements between the United States and members of the Mutual Security organizations (e.g., NATO, SEATO, OAS) include support with military supplies and equipment. Shipment of these goods must meet the same criteria as those which are transported to our own forces deployed in overseas areas. Adequate preservation, packaging, and packing procedures must be followed to ensure delivery of serviceable goods to a specific recipient.

Supplies and equipment shipped to memebers of Mutual Security Organizations will be preserved and packaged Level "A" unless otherwise specified by the contractor or organization concerned.

In some instances the markings may be bi-lingual for easy and more rapid identification of contents by handlers in the country involved. Markings and identification will be in accordance with MIL-STD-129. Refer also to Chapter 13, "Marking." Bi-lingual markings are considered as special markings and will be treated as such.

The Department of the Army Technical Bulletins in the TB 34-9 series, *Standardization of International Materiel,* may give some guidance to packaging and packing requirements in relation to Mutual Security Organization shipments of supplies and equipment. These bulletins can be found listed in the Department of the Army Pamphlet No. 310-4.

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TB 34-9-137, *NATO Code of Colors for Identifying All Ammunition 20MM in Caliber and Above.*

TB 34-9-143, *NATO Standardization Agreement for Airborne Stores and Associated Suspension Equipment (STANAG 3441).*

TB 34-9-246, *Handling and Documentation of Dangerous Cargo for Air Transportation.*

TB 34-9-249, *Marking of Military Vehicles.*

GLOSSARY

abrasion. The damage caused by the scuffing or friction of a part against its package, or of a package against an external object.

absorption. The penetration of one substance into the mass of another.

adhesive. A material used to join surfaces to each other. The term applies to cement, glue, mucilage, paste, and thermoplastic adhesives.

adhesive, pressure-sensitive. An adhesive that requires only briefly applied pressure at room temperature for adherence to a surface.

adsorption. A concentration of a substance at a surface or interface resulting from the attraction of molecules of the two substances; e.g., the condensation or adhesion of gases, liquids, or dissolved substances on the surface of solids.

anchoring. The securing of an item to the base of a shipping container by means of bolts, tie rods, tie-down timbers, or steel strapping to prevent movement.

anode. The positive electrode through which an electric current enters an electrolyte.

ASTM. American Society for Testing Materials.

baffle. A piece of plywood, wood, or metal placed over ventilation holes to deflect air or water entering the crate.

barrier. An obstructing agent serving to separate one element or space from another, or limit the migration or infiltration of one element into the other.

barrier material. A material designed to withstand, to a specified degree, the penetration of water, oils, water vapor, or certain gases. May serve to exclude or retain such elements without or within a package.

box, cleated fiberboard. A rigid container having four to six cleated panel faces made of solid or corrugated fiberboard.

box, cleated plywood. A rigid container having four to six cleated panel faces made of plywood.

box, corrugated and solid fiber. A rectangular three-dimensional shipping container, made either of solid fiberboard or of corrugated fiberboard. The major types are:

a. center special slotted box
b. five panel folder
c. full flap slotted box
d. one-piece folder
e. overlap slotted box
f. regular slotted box
g. telescopic design box.

box, set-up. A specific kind of carton, three-dimensional and rigid in construction, and delivered in the finished form.

box, wire bound. A shipping container whose sides, top, and bottom are of rotary cut lumber, sliced lumber, resawn lumber, fiberboard or a combination, fastened to cleats and to each other by means of binding wire and staples.

carton. A form of package used in interior packing made from bending grade of paperboard. The term is generally recognized as the acceptable designation for folding paperboard boxes, not shipping containers.

cellulose. A carbohydrate constituent of the walls and skeletons of vegetable cells.

center special slotted box. A box designed so that the inner and outer flaps meet in the center giving a double thickness for top and bottom.

centipoise. A measure of viscosity, the resistance to shear stress of a liquid, conveniently and approximately defined as the viscosity of water at room temperature.

check. Split or crack in wooden boards, staves, or heading.

cleats. Pieces of material, such as wood or metal, attached to a structural body to secure, strengthen, or furnish a grip.

clinch. After nailing, to bend or turn over the protruding points so that nails will hold fast.

cube. A conventional method of expressing volume occupied by an item or package in ocean shipping where the volume is expressed in cubic feet and twelfths of a cubic foot. In principle, it is the product of the three dimensions of the smallest rectangular prism into which the package will fit. Also, the cube shall be the cubic displacement of the containers or the item, whichever is the greater, calculated from its exterior over all length, width, and height dimensions, and

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unless otherwise required by the cognizant activity, shall be shown in cubic feet to the nearest 1/10 cubic foot, expressed decimally.

desiccant. A dehydrating agent. A material that will absorb moisture by physical or chemical means.

dew point. The temperature at which air or other gases become saturated with vapor, causing the vapor to deposit as a liquid. The temperature at which 100 percent relative humidity is reached.

DOT. Department of Transportation.

drum. A cylindrical shipping container having straight sides and flat, concave, or convex ends, designed for storage and shipment as an unsupported outer package that may be shipped without boxing or crating. May be made of metal or plywood or fiber with wooden, metal, or fiber ends. Drums are also made of rubber and polyethylene.

dunnage. Temporary blocking, flooring or lining, racks, standards, strip, strapping, stakes, or similar bracing or supports, not constituting part of a freight car, or cargo vessel used to protect or make freight secure in or on freight car or vessel.

five panel folder box. A box design consisting of a single scored slotted sheet. The outer end flaps fully overlap. This style box is used to an advantage in the packing of stacked or nested items which can be arranged on the flat scored sheet. The box can then, be folded over the contents.

humidifier. A device that causes water vapor to be diffused into the atmosphere of an enclosure, as in a freight car or storage compartment.

humidity, absolute. Mass of water vapor present in unit volume of the atmosphere, usually measured as grams per cubic meter. It may also be expressed in terms of the actual partial pressure of the water present.

humidity, relative. Water vapor in air. Relative humidity is the ratio of actual humidity to the maximum humidity which air can retain without precipitation at a given temperature and pressure. It is expressed as a percent of saturation.

impact strength. Resistance of a material or item to shocks such as from dropping and hard blows.

inhibitor. A substance or agent that slows or prevents chemical reactions such as those of corrosion, oxidation, adhesive deterioration, even though present only in small quantities.

interior cushioning, material used for. Animal and vegetable fibers, corrugated board, excelsior, glass wool, expanded mica, diatomaceous earth, shredded paper, foam rubber, foam plastics, creped cellulose wadding, indented chipboard, sawdust, shavings.

ionization. A condition occurring when an acid, base, or salt is dissolved in water. A part or all of the molecules of the dissolved substance are separated into electrically charged parts called ions.

moisture. The liquid state of a liquid such as water.

nail, anchor. A cement-coated nail designed for use with anchor strapping and doorway-protection retaining strips.

nail, anchor plate. A ringed nail for use with anchor plates, mechanical brakeman plates, and holdfast cleats.

nail, cement-coated. Nail to which a coating has been applied to increase its holding power.

nail, cooler. Same as sinker except that the head is flat underneath and of slightly greater diameter than a sinker of the same penny-size.

nail, corker. Nail with flat counter-sunk head. (*See* **nail, sinker**).

nail, etched. Nail with surface roughened by etching in acid bath. Has more holding power than cement-coated nails.

nail, sinker. Nail similar to the corker nail, but of slightly smaller gage and diameter of head. Heads of both the sinker and corker types resist breaking or pulling off better than flat head types.

one-piece folder. Also known as a book wrapper. When box is closed, the outer flaps must meet. Unless otherwise specified, the inner flaps will not be less than 2 in. long for folders under 18 in. in width, and not less than 3 in. long for folders 18 in. and over in width.

overlap slotted box. When closed, the inner flaps of this style box must not overlap, and the outer flaps will overlap the distance specified in the order or invitation for bids. The inner flaps will be of the same length as the outer flaps, except when the relation of width to length would cause the inner flaps to overlap. In this event, the inner flaps must be cut to meet in the center of the box.

pallet. A low, portable platform of wood, metal, fiberboard, or combinations thereof, to facilitate handling, storage, and transportation of items as a unit.

paperboard. Board made of matted or felted fibrous material and more than 0.012 in. thick. This distinction between paper and paperboard is arbitrary because some materials of this thickness are sufficiently flexible to be papers, whereas others in the range of 0.009 in. are exceptions and are considered boards because of their stiffness. Thus, caliper and stiffness are both factors in the utility of paperboard for box making. Nevertheless, paperboard and boxboard are not synonymous terms. Boxboard is a specialized form of paperboard.

permeability. The property of allowing gases or liquids to pass through a material.

plastic. Any one of a large group of materials, of high molecular weight, consisting wholly or in part of combination of carbon with oxygen, hydrogen, and other elements which, while in the finished state, at some state in its manufacture can be made to flow, and thus is capable of being formed into various shapes, most usually through the application, either singly or together and under control of heat, pressure, or time. Plastics are of two types:

a. thermoplastics–those which repeatedly become soft when exposed to heat and harden again when cold.

b. thermosets–those which set into permanent shape in processing under heat and pressure and do not soften upon reapplication of heat and pressure.

plastic films, types of.

a. cellulose acetate
b. rubber hydrochloride
c. vinyls and copolymers thereof
d. cast vinyl
e. polyethylene
f. styrene and copolymers thereof
g. ethyl cellulose
h. polyvinylidene chloride.

plastic, nonrigid. A plastic that has a stiffness or apparent modulus of elasticity of not over 50,000 psi at 25°C when tested according to ASTM test methods.

poise. The cgs unit of absolute viscosity, derived from Poiseuille, discoverer of the laws of flow. A centipoise is one-hundredth of a poise. Water at 20.2°C has a viscosity of one centipoise.

regular slotted box. This design requires that all the flaps be of equal length. The outer flaps must meet in the center when closed. This is the most commonly used box style.

skid. Metal or wood platform considerably raised on side members or legs to allow entry of truck forks or low lift-equipment. Lacks the bottom cross members of a pallet. One of a pair or series of parallel wooden runners affixed to the underside of boxes or crates to allow entry of truck forks.

storage life. The period of time during which a packaged item can be stored under specific temperature conditions and remain suitable for use. Sometimes called shelf life.

tare weight. The weight of the container or packaging materials. When a container is filled, or partially filled, the weight of the contents is termed the net weight, the weight of the container is the tare weight. The net weight added to the tare weight is the gross weight.

telescopic design box. The design consists of both a top and bottom tray. The depth of the bottom tray is made equal to the overall depth of the top tray. This style of box has a triple thickness of fiberboard on all four corners when closed, affording good stacking strength.

truck, lift, fork. A vehicle with vertical, elevating back plates and horizontal forks, for raising loads. Used for short distance hauls in warehouses, vanloading, and for stacking palletized items.

vacuum packaging. Packaging in containers, whether rigid or flexible, from which substantially all air has been removed prior to final sealing of the container. Such vacuum containers or packages must be constructed of barrier materials and so formed that a satisfactory degree of vacuum is retained during the expected period of use.

vapor. The gaseous state of a liquid or solid such as water vapor.

volatile corrosion inhibitor. A chemical that slowly emits a vapor that reduces or is inhibitive to corrosion; usually applied to chemically treated paper used in packaging ferrous metal products. Also known as vapor phase inhibitor, VCI, VPI.

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